USING A.I AND MACHINE LEARNING EFFICIENTLY TO DECIDE ON VOYAGE FIXTURE OF TANKER SHIPS TO INCREASE TURNAROUNDS AND PROFITABILITY

by

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Dedication

This dissertation is devoted to all ship owners, managers, charterers, and maritime specialists, technologist who painstakingly find solutions to answers the problems encountered in the maritime sector. Our field advances more quickly because of your dedication to excellence, which motivates others to develop their skills.

I also want to dedicate this to my mentor Dr. Mario Silic, who had encouraged me at every step in this journey and whose guidance has given me a right direction, persistence & shaped my academic path and the also I would like to thank SSBM, Geneva for all the support.

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ABSTRACT

USING A.I AND MACHINE LEARNING EFFICIENTLY TO DECIDE ON VOYAGE FIXTURE OF TANKER SHIPS TO INCREASE TURNAROUNDS AND PROFITABILITY

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This research investigates how the use of Artificial intelligence (AI) & Machine learning (ML) concepts can forecast turnaround times at shipping ports, with a focus on the tanker shipping industry. The study intends to improve vessel turnaround efficiency by examining a variety of market conditions, which will ultimately result in higher profitability. It examines the Sales-and-Leaseback financial model to enhance profitability in ship ownership and management while mitigating liability risks. To extract valuable insights from the data and improve the analysis of market trends and operational efficiency, the utilization of Natural Language Processing (N.L.P) will be examined.

Keywords: Artificial Intelligence, Machine Learning, Merchant Shipping, Oil tankers, Ship Chartering, N.L.P, Sales-and-Leaseback.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

1.1 Introduction

According to the UNCTAD (2018), 80% of global trade by volume and over 70% of global trade by value are carried by sea and are handled by ports worldwide. The consequences of stoppages and delays in the maritime industry can disrupt the entire world as this was witnessed during blockage of the Suez Canal which handles 12% of global shipping by an Ultra Large Container Carrier (U.L.C.C) in March 2021 when the ship ran aground. If we consider the case of COVID-19 the global maritime industry kept constantly moving the goods playing a vital role. Maritime traffic data, collected via of Automatic Identification System (AIS) receivers were analyzed to find effects that the COVID-19 pandemic and the containment measures had on the shipping industry, which accounts alone for more than 80 % of the world trade (Clarkson's Research, 2017). It is essential to understand the functionality & disadvantages of using AIS & its information, this equipment is used in ship reporting. As per the definition Automatic identification systems (AIS) transponders are designed to be capable of providing position, identification, and other information about the ship to other ships and to coastal authorities automatically (International Maritime Organization, n.d.) divided into two subsets of "Dynamic" information such as Ship's position. Course over ground (C.O.G), Speed over ground (S.O.G), Heading, Navigation status (Vessel Underway, Moored or anchored etc.), Rate of turn etc. and "Static" information such MMSI number, IMO number, Vessel Name and Call Sign, Length and Beam (Breadth of Ship), Type of ship (Shilavadra Bhattacharjee, 2021). "Voyage-related" information such as ships draught, Hazardous cargo, Destination & ETA, route plan waypoints-at the discretion of the master (Ship's Captain).This information shouldn't be completely relied upon for any decision making since this information can be changed or not disclosed due to security reasons (BigOceanData, 2017).

The quality of data is essential to make productive use of Automatic Identification System (AIS) data.

As the huge volume that is collected, and the lack of quality make it difficult to capitalize on the potential of using this data (Tsou, 2010). It is also important to understand shipping's role in the worldwide economy and how time relates to the cost and the pressure the parties involved from the Shipowners, ship managers, crew onboard, charterers, brokers, receiver, and indeed us a consumer must face.

With the introduction of new maritime regulations on different grounds, the skyrocketing fuel prices these days and the research on developing a risk management tools to reduce unnecessary fuel cost risk, fuel price fluctuations and improving financial management and installation of equipment's such as Exhaust Gas Cleaning System (E.G.C.S) on the existing and new ships to purify the exhaust gas and choosing natural gas marine fuel are also emphasized (Han and Wang, 2021). These smart decisions are vital to avoid a downfall in the profits by decreasing operational costs. According to an article from McKinsey & Company commodity-related trends are likely to depress medium-term demand, but companies that can leverage deep market insights will have the opportunity to outperform in the post-crisis economy (Arjen Kersing et al., 2020).

Leveraging Artificial intelligence (A.I) and Machine learning (M.L) in any company can led to exponential growth as data is the fuel driving today's industrial economy including shipping to complement this advanced NLP models, such as GPT-4, LLaMa 3.2, and Gemini 1.5 Pro etc, provide refined insights across diverse maritime datasets, enabling data-driven decisions in fixture scheduling and route optimization (Ali, 2023).

Also, companies that invest in analytics can use data-led insights to seize opportunities in four main areas (Arjen Kersing et al., 2020):

1. Finding attractive subsectors and niches through insight into end customers,
2. Optimizing portfolios based on relative attractiveness and risk level of different vessel classes,
3. Improve commercial choices,
4. and operate vessels more effectively.

Within this expansive sector, tanker shipping plays a particularly critical role, facilitating the transportation of liquid cargoes such as crude oil, chemicals, and liquefied natural gas. Tankers are specialized vessels designed to handle these unique types of cargo, and their operational efficiency has significant implications for both economic performance and environmental sustainability.

As the demand for energy continues to grow, optimizing voyage fixtures, the process of arranging the chartering of tankers has become paramount for enhancing turnaround times and profitability in this competitive market. One of the biggest challenges facing tanker operators is market volatility, which can lead to significant fluctuations in freight rates (TSG Tanker Freight Market Dynamics | Industry analysis, news and rates, 2021). Factors such as geopolitical tensions, natural disasters, and changes in global oil production can drastically impact supply and demand dynamics, resulting in unpredictable operating costs and revenues (Hand, 2024). Consequently, ship owners must adopt better strategies that enable them to respond swiftly to these market changes (Clarkson's Research, 2017). Effective fixture optimization can minimize idle time and maximize the utilization of vessels, ultimately enhancing profitability.

In addition to market volatility, tanker operators must navigate an increasingly complex regulatory landscape. Stricter environmental regulations, such as the International Maritime Organization's Sulfur Cap (International Maritime Organization, 2020), mandate that vessels reduce their emissions, pushing shipowners to invest in cleaner technologies and compliance measures. This not only involves upgrading existing fleets with technologies such as scrubbers and ballast water treatment systems but also requires meticulous planning and management to ensure compliance with varying regulations across different jurisdictions (Han and Wang, 2021) .

The challenge of maintaining regulatory compliance adds another layer of complexity to voyage fixture decisions, necessitating more sophisticated operational strategies. Moreover, the operational intricacies of tanker shipping cannot be overlooked.

Factors such as route optimization, port congestion, and vessel scheduling all play a significant role in determining turnaround times (Dayananda Shetty K et al., 2021).

Delays in loading or unloading can lead to increased operational costs and lost revenue opportunities. Therefore, optimizing voyage fixtures becomes a multifaceted challenge that requires a comprehensive understanding of maritime operations, market conditions, and regulatory requirements. In this context, the integration of artificial intelligence (AI) and machine learning technologies offers transformative potential for tanker shipping. These technologies enable data-driven decision-making that enhances operational efficiency and reduces idle time. For instance, AI algorithms can analyze vast amounts of historical and real-time data to identify patterns and predict market trends, allowing ship owners to make informed decisions about when and where to fix their vessels. This predictive capability can lead to more favorable charter agreements, ultimately driving profitability. Furthermore, machine learning can optimize routing and scheduling by considering variables such as weather conditions, port congestion, and vessel performance which goes in line with statement mention by (Akyuz et al., 2019) on how adaptation of machine learning tools might provide utmost benefit for efficiency, sustainability and reduction of operational costs. By leveraging these technologies, tanker operators can dynamically adjust their voyage plans to minimize delays and maximize the efficiency of their operations. This agility is particularly important in a sector where timing can significantly impact financial outcomes. In addition to operational efficiencies, innovative financial models can enhance the competitiveness of tanker operators. One such model is the Sale-and-leaseback model which was the strategy used by low-cost airline known as “Indigo airlines” in India which drastically reduced its operational cost. While other airlines were at great loss, “Indigo” was making remarkable profits. As per the definition Leaseback, short for "sale-and-leaseback", is a financial transaction in which one sells an asset and leases it back for the long term therefore, one continues to be able to use the asset but no longer owns it. The transaction is generally done for fixed assets, notably real estate, as well as for durable and capital goods such as airplanes and trains (WIKIPEDIA, 2021).

This is how “Indigo” applied this strategy as they ordered a bulk order of 100 Airbus A320 aircrafts a year after it was launched, when other airlines don’t even venture into such deals (HBS Digital Initiative, 2015). During the time “Airbus” was striving hard to come back into the Indian market whereas this deal helped them to enter the Indian aviation market, as well as Indigo was given huge discounts on the purchase order of those aircrafts which is believed to be close to 50% by market experts & almost same discount were given to “Indigo” in 2021, when “Indigo” ordered 255 A321 neo passenger jets (Hepher (Reuters) and Creidi (Reuters), 2021). This is how massive discount deal would workout with Sale-and-leaseback model for “Indigo” airline, assuming “Indigo” purchased a 100 million USD aircraft for a price of 50 million USD from Airbus (manufacturer), it would sell those aircraft (asset) to the other party (BOA Leasing company) at 55 million USD with a profit margin of 5 million USD per aircraft and rent its back from the BOA Leasing company for the period of 5-8 years whereas “Indigo” would pay the rent from its operating cost. For a leasing company like BOC aviation, it would be great deal to get a brand-new aircraft at such a low cost instead of spending 100 million dollars they would get the aircraft at 55 million USD and without taking the risk of ordering so many aircrafts and this will also help them to get the readymade customer base that will give them a constant revenue. But this helped "Indigo” with some great benefits against its competitors firstly, company gets upfront profits of 5 million USD per aircraft which helped to boost its cash flows where other airlines struggled during the same time, secondly “Indigo” ensured that not all the aircraft are delivered at once, but there will be gap of 6-8 weeks between each delivery so that they can steadily accommodate those aircrafts as per market conditions (Timothy ROSS, 2021). The third factor was any technical glitch, or any issues related to the engine were to be taken care of by either Airbus or the engine manufacturer, this way the airline didn’t have to pay for the maintenance staff & nor for the maintenance. This is how Indigo used way more aircraft with very less capital cost compared to its competitors, making them cash rich. This same strategy can be used by the Ship owners by purchasing ships in bulk to get higher discounts from the ship manufacturers & sell it to a leasing company with profit margins and then rent it back from them again using the same strategy of

Sale-and-leaseback model which would reduce the ship owner’s liability, and they could expand their operations to a larger extent and at the same time they can have a great cashflow**.** The future of tanker shipping hinges on the ability to leverage technology and innovative strategies to navigate these complexities, ensuring that operators can meet the demands of global trade while achieving financial sustainability.

1.1.1 Challenges in Voyage Fixtures

Voyage charter agreement or Voyage fixtures are essential agreements that specify the terms under which vessels are chartered for cargo transport, particularly in the tanker shipping sector (Menon, 2021). These fixtures are critical not only for establishing the price and terms of service but also for ensuring that both shipowners and charterers have clear expectations regarding operational procedures and timelines. However, the complexity of securing these fixtures is influenced by a myriad of factors that lead to substantial operational and financial challenges for stakeholders in the industry.

1.1.2 Fluctuating Demand

One of the primary challenges in tanker shipping is the unpredictability of demand for cargo transport. Following the naturally recurring ups and downs of the tanker shipping industry, demand volatility further complicates the process of voyage fixtures, impacting freight rate stability and strategic planning. According to a study conducted on freight markets volatility by (Lim et al., 2019) this analyzes the drivers of freight market volatility, highlighting the complex relationship between broader economic conditions and shipping-specific factors that influence supply and demand. Their findings reveal that volatility in freight markets is shaped by the spot rate level, the slope of the forward curve, and various supply and demand dynamics, with demand factors being especially impactful. Notably, the study demonstrates that the relationship between futures price volatility and the forward rate slope is V-shaped and nonlinear.

This means that anticipation of economic growth and a stronger freight market generally lowers implied volatility (IV), while greater uncertainty or expected excess shipping capacity tends to increase IV. The study's robustness, supported by panel regressions, underscores how critical these economic and market factors are in influencing volatility, which tanker operators must consider when optimizing their operational and financial strategies.

1.1.3 Regulatory Challenges

The shipping industry is subject to a myriad of international and national regulations that can change rapidly, creating a complex operational landscape for shipping companies. Compliance with environmental regulations, safety standards, and trade laws can significantly complicate operations and increase costs, making it essential for stakeholders to stay informed and adaptable. A key example is the International Maritime Organization (IMO), which has introduced various regulations aimed at mitigating the environmental impact of shipping. Notably, the IMO 2020 sulfur cap mandates a substantial reduction in sulfur emissions from vessels, requiring shipowners to make substantial adjustments to their operations (IMO, 2020).

These regulatory changes often necessitate costly upgrades to vessels, such as retrofitting existing ships with scrubbers to comply with emissions standards or transitioning to alternative fuels like liquefied natural gas (LNG) as mentioned by (Han and Wang, 2021). Such modifications can be both time-consuming and capital-intensive, placing a financial strain on operators, particularly smaller companies with limited resources. Moreover, the need for compliance can lead to delays in securing voyage fixtures. If a vessel fails to meet new compliance standards, it may be temporarily sidelined, unable to undertake voyages until necessary modifications are completed. This situation not only affects the revenue of the shipowner but also disrupts the broader supply chain, as cargo cannot be transported as planned.

Delays in vessel availability can create a ripple effect, impacting charterers who rely on timely deliveries, and potentially leading to contractual penalties or lost business opportunities.

Furthermore, the dynamic nature of regulatory frameworks means that shipping companies must continuously monitor changes and be prepared to adjust their strategies swiftly. This agility requires investment in both human resources and technology to ensure compliance without compromising operational efficiency. Considering these challenges, shipping companies are increasingly prioritizing proactive compliance strategies. This includes investing in training for crew and management to understand and implement new regulations effectively, as well as exploring innovative technologies that enhance compliance while optimizing performance (Lasater, 2023). Additionally, fostering strong relationships with regulatory bodies can help companies stay ahead of changes and navigate the complexities of compliance more smoothly. By taking a proactive approach to regulatory challenges, shipping companies can mitigate the risks associated with compliance, maintain operational continuity, and better position themselves for success in an evolving maritime landscape.

1.1.4 Port Congestion

Port congestion remains a major challenge, directly impacting tanker efficiency and often resulting in significant financial setbacks. When several vessels vie for limited berthing spots, delays are inevitable, extending laytime (the time allowed for loading or discharging cargo) which is key to profitability. Long lay times mean vessels sit idle rather than moving on to their next journey, creating financial strain that can ripple through the entire supply chain. The reasons behind port congestion are complex and interconnected. Rising global trade, fueled by economic growth and evolving consumer habits, drives up demand for port services. Inadequate infrastructure such as limited berths and outdated cargo handling systems adds to the strain, creating bottlenecks that slow down operations. Logistical inefficiencies, like uncoordinated scheduling and limited stakeholder collaboration, only deepen the issue.

A recent, study from the (World Bank, 2021) even shows that these inefficiencies in port operations contribute to economic losses in the billions each year, not just from idle ships but also from delays in cargo delivery, which can lead to penalties and missed market opportunities.

1.1.5 Geopolitical Factors

Geopolitical influences add an extra layer of complexity to the operational aspects of tanker shipping, especially in terms of planning voyage fixtures. Events such as regional conflicts, international sanctions, and political instability not only disrupt well-established shipping routes but also limit vessel availability, often leading to higher operational costs and uncertainty.

Take, for instance, the ongoing tensions around the Strait of Hormuz a critical passage for oil transport worldwide. As (Lott and Kawagishi, 2022) pointed out the heightened risks in regions like this often-prompt operators to increase insurance coverage and factor in higher costs to safeguard against possible disruptions. This need for extra insurance contributes to rising operational expenses, which can push up overall fixture prices, as charterers may hesitate to commit to voyages through high-risk areas.

Additionally, changes in trade policies or the imposition of sanctions can shift demand for particular routes in unpredictable ways. For example, sanctions targeting countries such as Iran or Venezuela often result in sudden redirections in trade flows (The Maritime Executive, 2024), which reduces the demand for tanker services in these areas. As a result, tanker operators need to have a robust risk management plan to anticipate such changes. A proactive stance can make a significant difference, as companies that spread their routes across multiple passages avoid over-reliance on any single path, effectively diversifying their exposure to potential disruptions.

It is of utmost importance to be informed on political developments, which is just as crucial. By investing in analytics and intelligence systems to monitor global political landscapes, shipping companies are better equipped to make informed choices regarding route selection and fixture negotiations.

Finally, strengthening relationships with local stakeholders in these politically sensitive areas is valuable for gaining access and ensuring compliance. By collaborating with local authorities, agents, and industry partners, shipping companies often receive timely insights into regulatory requirements and emerging risks, which helps maintain smoother operations in complex regions. This flexibility not only fosters better charter agreements but also reinforces a company's overall operational resilience, a necessary trait to thrive in an unpredictable geopolitical landscape.

1.1.6 Importance of Quick Turnaround Times

In tanker shipping, quick turnaround times are essential not just for company profitability but also for maintaining smooth global trade. When a vessel stays in port or anchorage for too long, it accumulates costs rather than earnings, placing constant pressure on shipping companies to reduce laytime and maximize utilization (Dayananda Shetty K et al., 2021). One effective way to achieve this is by improving operations in multiple areas. For example, digital tools like AI-driven predictive analytics and IoT sensors now offer real-time tracking of vessels, cargo, and port activities. These technologies allow companies to respond quickly to delays, adjusting schedules and routes to minimize downtime (Durlik et al., 2023).

In addition, forming strong partnerships with stakeholders such as charterers, port authorities, and crew is crucial. These partnerships foster smooth communication and enable coordinated responses to potential issues, allowing for faster and more efficient turnaround times. However, implementing these strategies requires ongoing coordination, shared scheduling, and sometimes considerable financial investments, especially in training programs.

Investing in thorough training for crew and staff is also key. When a team is well prepared, they can better handle unexpected issues, such as mechanical breakdowns or port state inspection inspections, ensuring minimal delays and safer operations (Pike et al., 2019).

1.1.7 Role of Artificial Intelligence (AI), Machine Learning (ML), and Natural Language Processing (NLP) in Tanker and Shipping Industries.

AI, ML, and NLP, particularly larger language models (LLMs) and Retrieval-Augmented Generation (RAG), are boosting the tanker and maritime industries in general. These technologies provide automation, data driven decision making, and real time insights, helping organizations respond to market changes.

Predictive Analytics and Decision-Making

Predictive analytics leverages historical and real-time data to forecast demand, optimize fixture schedules, and manage risks. By anticipating trends like seasonal demand or market shifts, companies align fleet capacity with needs, reducing downtime and increasing revenue (Marine Digital, 2024).

Route Optimization

ML-driven route optimization evaluates factors like weather, port congestion, and ocean currents to recommend efficient routes, cutting both fuel costs and transit times according to study conducted by (nextbillion.ai, 2024). By selecting optimized paths, companies enhance profitability and environmental compliance by reducing emissions. Getting recommendations for optimized routing has a direct impact on reducing costs and increasing the operational sustainability of tanker shipping.

Real-Time Data Processing and Collaboration

AI's real-time data processing provides operators with immediate insights for timely adjustments to avoid disruptions, such as port delays. Centralized platforms also support enhanced collaboration among stakeholders, improving communication between ship owners, charterers, and port authorities for smoother coordination (Kersing et al., 2020), AI -facilitated collaboration will foster a more agile and adaptive shipping environment.

Natural Language Processing for Data Insights

Natural language processing refers to the branch of computer science and more specifically, the branch of artificial intelligence (AI) concerned with giving computers the ability to understand text and spoken words in much the same way human beings can (IBM, 2020). Early NLP models such as GPT-J, BERT, and Pegasus laid the groundwork for summarizing reports and analyzing data in maritime contexts.

Specialized models like Google TAPAS and TaBERT further advanced NLP's utility by efficiently handling tabular data, which is crucial for processing structured datasets like historical voyage data and regulatory trends.

Building on these foundational tools, recent advancements in large language models (LLMs) have significantly enhanced NLP's capabilities. The latest models, such as OpenAI GPT-4, LLaMa 3.2, Gemini 1.5 Pro, Claude, and Mistral, offer greater accuracy, scalability, and flexibility, allowing for more refined insights across diverse maritime datasets. According to (Ali, 2023), Retrieval-Augmented Generation (RAG) models, coupled with vector databases, facilitate precise, real-time information retrieval, enabling tanker operators to make data-driven decisions in areas such as fixture scheduling, route optimization, and regulatory compliance.

A notable advancement in modern LLMs is the integration of conversational AI with memory, allowing for extended interactions that retain contextual information (Liu et al., 2024). This feature is especially valuable in complex maritime operations, where insights evolve based on accumulating data. By interfacing LLMs with predictive analytics outputs through APIs, shipping companies can enhance insights with dynamic parameters like weather forecasts, port congestion, and market trends.

For instance, processing a predictive analysis report through an LLM prompt that includes real-time weather data allows stakeholders to receive a tailored, comprehensive outlook that informs actionable decisions.

The use of platform like AWS Bedrock or LangChain further enriches these capabilities by enabling seamless integration of multiple LLMs and data sources into unified applications using vector databases (AWS, 2023; Mondragon, 2023). This approach facilitates more detailed insights for stakeholders, optimizing decision-making across various operational scenarios.

According to (Biddwan, 2024) study done on the NLP tools, they offer critical support in extracting insights from complex data to improve decision-making.

Operational and Financial Benefits

AI-driven automation reduces routine tasks and errors, enabling personnel to focus on strategic work. Through optimized fuel usage, reduced laytime, and minimized port fees, AI contributes to cost savings and increased profitability. Shorter turnaround times, improved fixture agreements, and data backed insights from NLP reinforce a competitive advantage, making AI, ML, and NLP essential for a resilient shipping model highlight that these efficiencies strengthen profitability and adaptive capacity in a fast-paced market.

1.2 Research Problem

A notable deficiency in the marine industry, especially in the tanker shipping sector, is the inadequate incorporation of AI and ML technologies to tackle these operational difficulties. Although challenges including variable charter rates, crew transitions, and regulatory constraints are extensively recorded, existing decision-making technologies inadequately offer predictive insights that could enhance voyage arrangements and chartering processes.

This research seeks to address this gap by investigating how AI/ML technologies might assist shipowners in real-time chartering and turnaround management, hence improving efficiency and profitability. Natural Language Processing (NLP) techniques are particularly relevant for extracting valuable insights from the extensive historical data generated within the maritime industry. By leveraging NLP, shipowners and managers can analyze past voyage records, regulatory trends, and market behaviors to inform current decisions.

This capability enables more precise predictions around optimal chartering routes, turnaround scheduling, and compliance measures, adding depth to decision-making processes that traditional tools lack.

Due to several operational and financial problems, the tanker transport industry is in a tight spot. The tanker shipping sector is currently seeing several significant issues within the marine industry. These difficulties also apply to other kinds of vessels, such as gas carriers, bulk carriers, container ships, and RO-ROs. The continued COVID-19 effects, the crew transition crisis, and strict regulatory requirements are important concerns.

According to (Clarkson’s Research, 2017; The Hindu BusinessLine, 2018), the introduction of cap and floor rates for charter hire has intensified competition and economic pressure on tanker operators. Moreover, the annual introduction of new maritime regulations focuses on safe ship operations, environmental protection, and crew welfare, necessitating costly upgrades to equipment like installation Exhaust Gas Cleaning Systems (E.G.C.S) has become crucial for lowering emissions and controlling fuel costs, as emphasized by (Han and Wang, 2021), Ballast Water Treatment Systems (B.W.T.S) are now critical to prevent the transfer of invasive marine species, in line with approved Ballast Water Management Plans (B.W.M.P).

Additionally, the industry faces substantial pressure to reduce Greenhouse Gas (G.H.G) emissions, which is a cornerstone of the decarbonization goals set forth by the (International Maritime Organization, n.d.).

These challenges underscore the complexity of managing maritime operations, which require rigorous compliance with numerous regulations and certifications to maintain the seaworthiness of vessels. Given the substantial capital investments involved, ship owners must ensure that their vessels remain in active service to avoid costly layoffs and ensure profitability.

To improve financial flexibility, shipowners may consider implementing the sales-and-leaseback model, which allows them to convert vessels into liquid assets while retaining operational control.

This approach not only enhances cash flow but also reduces debt obligations, helping shipowners meet the high costs of regulatory compliance and environmental upgrades.

The financial health of shipowners and stakeholders depends on generating sufficient revenue from vessel operations to fund necessary upgrades and comply with evolving industry standards. There is a clause drafted between both the shipowners and the charterers to navigate contractually within a time charter party context according to (Baltic and International Maritime Council (BIMCO), 2022). In this context, it is crucial for shipowners to avoid losses during fixed voyages as per the Charter Party (CP) clauses, especially in cases of negligence or unavoidable circumstances. To better understand these dynamics, this research will address several key questions from the perspectives of shipowners and stakeholders, focusing on how trade is conducted and potential solutions to these challenges.

1.3 Purpose of Research

The purpose of this research is to explore how Artificial Intelligence (AI), Machine Learning (ML) including Natural Language Processing (NLP) can be effectively applied to improve decision making in voyage fixture and turnaround processes for tanker ships. By leveraging these advanced technologies, the study aims to enable shipowners to optimize routing, streamline chartering practices, and enhance compliance, all contributing to increased turnaround speeds and profitability.

In addition, this research will examine the sales-and-leaseback financial model as a strategy to boost financial flexibility for ship owners. This approach is intended to help stakeholders convert vessels into liquid assets while maintaining operational control, ultimately supporting cash flow and reducing financial risk.

This study aims to deliver practical recommendations for the tanker shipping sector through expert insights, analysis of present practices, and a comprehensive methodological methodology. These insights will enable decision-makers to implement data-driven initiatives that enhance operational efficiency and profitability, assuring sustainable growth in a competitive marine environment.

1.4 Significance of the Study

This study provides critical insights to help the tanker shipping industry improve operational efficiency, compliance, and profitability. By using AI, ML and NLP, the research aims to offer ship owners data driven methods for optimizing key processes like chartering, routing, and voyage planning. This approach addresses both the need for faster turnaround times and the challenges of meeting regulatory requirements.

Recent advancements in NLP, including memory enabled LLMs platforms like AWS Bedrock & LangChain can integrated multiple models like GPT-4, LLaMa 3.2, and Gemini 1.5 Pro in conjunction with vector databases and other input source of information which will allow for real-time data integration and adaptive decision-making as mentioned above. These tools enable stakeholders to incorporate dynamic inputs, such as Predict analysis data, weather conditions, port congestion, machinery performance directly into LLM model, where system can build to make an AI based platform, enhancing strategic insights and responsiveness.

In addition, the exploration of the sales-and-leaseback model offers shipowners a practical financial strategy to enhance liquidity and manage costs in a volatile market. This solution is timely, given the sector's financial pressures and increasing regulatory demands.

Beyond direct industry applications, the study contributes to broader maritime research by promoting innovative, data-focused practices for sustainable growth and resilience in global shipping.

1.5 Research Purpose and Questions

This research aims to provide the tanker shipping industry with strategies that leverage AI, ML, and NLP to optimize key operations, particularly in voyage fixture decisions, chartering, and turnaround processes. The study also seeks to determine the effectiveness of the sales-and-leaseback model as a financial strategy to enhance liquidity while maintaining vessel control, helping shipowners navigate financial and regulatory challenges.

The following research questions will be addressed through this study, utilizing advanced AI, Machine Learning (ML), and Natural Language Processing (NLP) techniques to uncover key insights and bridge existing gaps within the tanker shipping industry.

By leveraging these technologies, this research aims to provide data driven solutions to address the identified challenges and enable strategic improvements for industry stakeholders.

RQ.1: How do ship owners fix their ships on charters at present day?

RQ.2: What are the associated problems they face and the barriers?

RQ.3: How can the Sales-and-leaseback financial model be applied by ship owners and managers efficiently in the maritime industry to become competitive and generate more profits?

Through addressing these questions, the study intends to offer actionable insights and recommendations that support efficiency, profitability, and resilience within the maritime industry.

CHAPTER II

REVIEW OF LITERATURE

2.1 Theoretical Framework

According to (Sreekumar, 2023) a theoretical framework serves as the structure supporting and explaining a theory, defining a set of interrelated concepts that provide a systematic view of phenomena by illustrating relationships among variables to explain these phenomena. A preliminary review of literature indicates that past studies have largely focused on the advantages of using machine learning in maritime transportation, particularly in addressing various maritime business issues such as voyage optimization, economic forecasting, transportation sustainability, freight rate control, and maintenance forecasting (Han and Wang, 2021). For instance, sustainability in shipping can be enhanced through machine learning applications that improve vessel efficiency by reducing fuel consumption (Pena et al., 2020) To develop effective research solutions, it is crucial to begin by understanding the current challenges faced within the maritime industry.

This Shipping sector in general has traditionally been sluggish in adopting new technologies, leading to a lag in the implementation of innovative solutions being a part of same ecosystem the tanker shipping industry is facing number of significant challenges, which includes the need for quick well-informed judgments improving sustainability issues as well as profitability.The aim of this research is to investigate how Artificial Intelligence (AI), Machine Learning (ML) and Natural Language Processing (NLP) might help address these problems. It highlights the capacity of data-driven insights to improve financial performance and operational efficiency.

Furthermore, the framework explores the sale-and-leaseback financial model as a means to strengthen financial flexibility, thereby supporting sustainable operations and meeting regulatory standards.In the next sections based on our Literature review we will identifies to key issues existing in the tanker shipping industry in the present market.

2.2 Impact of Crude oil demand and supply imbalance & COVID 19.

The fluctuation in oil prices and the tanker markets associated risk of crude oil price fluctuations have been emphasized in the research conducted in past (Shi et al., 2013). Crude oil prices are governed by global supply and demand. Economic growth of the nation is one of the factors that increases in demand of energy and so in the demand of Petroleum products and in turn crude oil (US Energy Information Administration (EIA), 2021). The Organization of the Petroleum Exporting Countries (OPEC) manages oil production of its member countries by setting crude oil production targets, or quotas, for its members hence it has a significant influence on oil prices. This includes countries with some of the world's largest oil reserves. As of the end of 2018, OPEC members controlled about 72% of total world proved oil reserves, and in 2018, they accounted for 41% of total world crude oil production (US Energy Information Administration (EIA), 2021).

In the graph shows the pattern of increase & decrease in demand of US refiner cost of Crude oil in USD per barrel from 1975 to 2020.

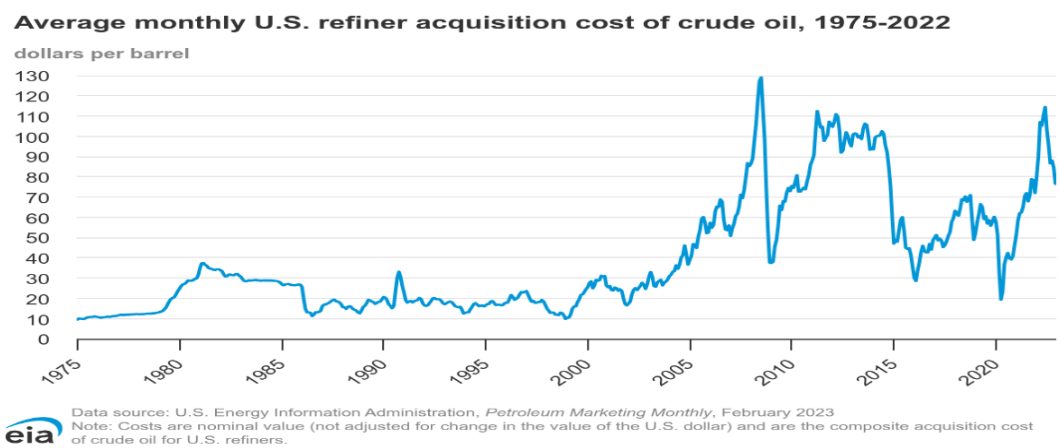

Figure 1. Average monthly U.S. refiner acquisition of Crude oil, 1975-2020 (US Energy Information Administration (EIA), 2021)

In response to these fluctuations in price is concerned, Iran would no longer export its crude oil in dollar payment. The payments would be accepted in local currencies, thereby reducing the risk of fluctuation. The above stated facts by (Shi et al., 2013) & statistics by the (US Energy Information Administration (EIA), 2021) clearly explains that the supply and demand of oil can affect the supply chain and indeed tanker shipping industry which can cause change in the time charter price (the price at which ship will be hired from ship owner). A good example of this would be when the oil prices drop the oil tanker ship charter price increase due to sudden surge of oil demand as to acquire more oil at less price especially during the pandemic (Baltic and International Maritime Council (BIMCO), 2020).

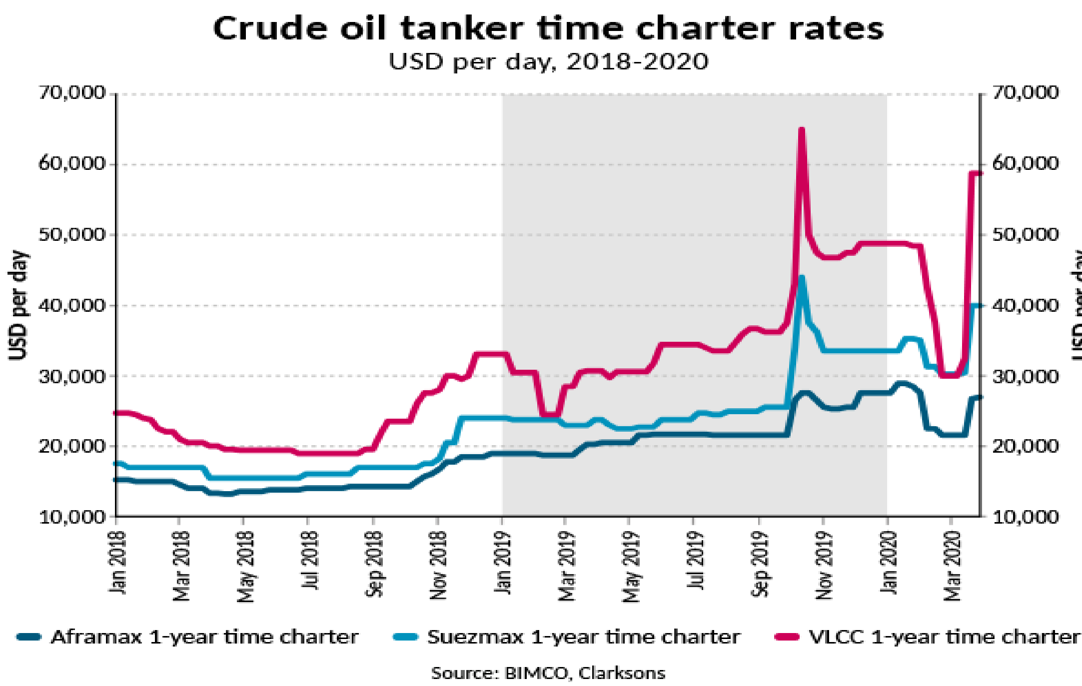

Figure 2. Crude oil tanker time charter rates (Baltic and International Maritime Council (BIMCO), 2020)

2.3 Impact of COVID-19

The Social and economic effect of COVID-19 has been devastating. According to (World Health Organization (WHO), 2020) tens of millions of people are at the risk of falling into extreme poverty. The entire industrial economy has also been badly impacted. A global downturn in the shipping industry will put significant pressure on financial undertakings & also this may adversely impact a shipping company's projected cash flows, such as a decrease in future charter rates, increase in off-hire days, increase in fuel prices, increase/decrease in operating expenses, increase in inflation, increase in a company's discount rate (if applicable), etc (PwC Greece, n.d.). On the other hand, the shipping industry is expected to benefit primarily from COVID 19's capacity to provide a better understanding of the causes of accidents and their prevention. Therefore, the shipping industry would be able to reduce the number of accidents and incidents, thereby reducing the cost of insurance and the cost of ship ownership.

2.4 Impact of International Politics on Tanker market

Major commercial routes of countries are dependent on oil, which means that if any of these region of those countries does political moves, commercial transportation will badly be affected. The relation of tanker shipping industry with Iran has also led to significant political issues as in July 2020, the oil tanker ship "Gulf Sky" vanished from waters off the United Arab Emirates, along with its crew. Days later it turned up in Iran where it's now suspected to be working as a "ghost ship" helping the regime ferry oil in breach of sanctions (BBC, 2020).

2.5 Overcapacity

Tanker shipping is facing another problem, which is overcapacity. It is an area in which there is an excess of ships supplying inadequate markets rather than moderating the demand. According to (FORBES, 2018) due to excess capacity, earnings was very low, with an average of $6,001 per day for Very Large Crude Carriers (VLCCs) and the Suez-max tanker earning $10,908 per day.

Compare that with $60,000 and $40,000 (respectively) in January of 2017. The underlying reason is far too many Very large crude carriers (VLCCs) in operation, owing to cuts in production by oil exporting nations, and lower U.S. import volumes, as local oil becomes more prevalent. Though tankers carrying capacities have increased by 50 percent in the last century. Two principal points to this overcapacity, one being overbuilt ships built for the utilization of the Chinese investment incentive program as Chinese quest for oil security to guarantee its oil supply during times of crisis (Oil & Gas Journal, 2006).

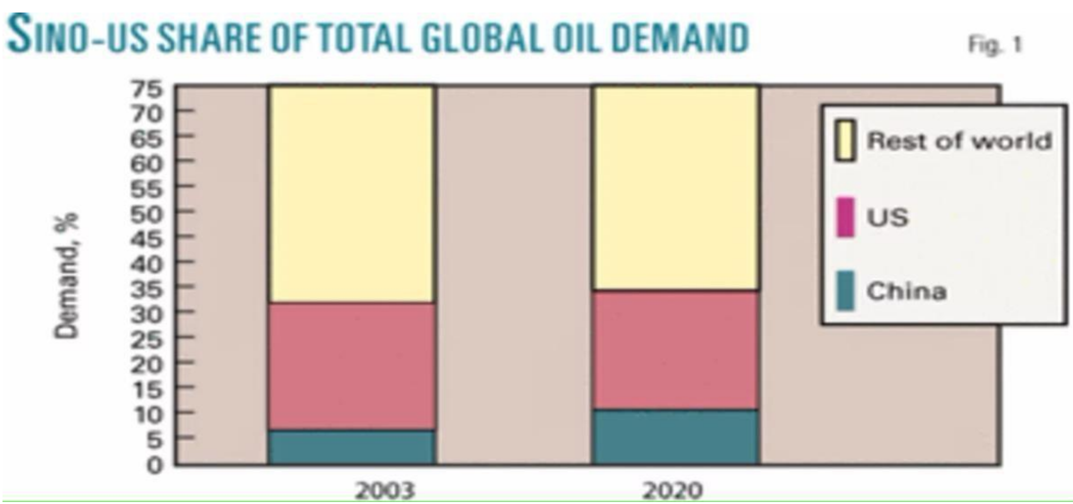

Figure 3. SINO-US share of total global oil demand 2003-2020 Source: (Oil & Gas Journal, 2006)

The other being that the shipping industry has increased their ships gross tonnage due to there being little regard for what products are being carried or the market region or the reliability of buyer credit. In terms of statistical affordability, the undercutting rate is an amount of money equal to the total amount of money being sunk into the transportation divided by the amount of money earned from it. Indeed, companies gain more profit as the rate is a declining value.

When the rates are low, tankers are deployed at more than full utilization and their operations are more efficient (Oil & Gas Journal, 2006).

2.6 Turnaround timing of tankers Ships-Turnaround Management

The tanker shipping industry has become highly competitive due to increasing demand for oil & associated products. Understanding about "Turnaround timing" is quite essential as per the definition the time that is taken between the arrival of a vessel and its departure is referred to as the turnaround time. The vessel turnaround time is used to measure the efficiency of port operations (cogoport, n.d.)

Turnaround time is one of the most significant port performance indicators, this is the total time spent by the vessel in port, during a given call.

It is the sum of waiting time, plus berthing time, plus service time (i.e., ship's time at berth), plus sailing delay (Dayananda Shetty K et al., 2021).

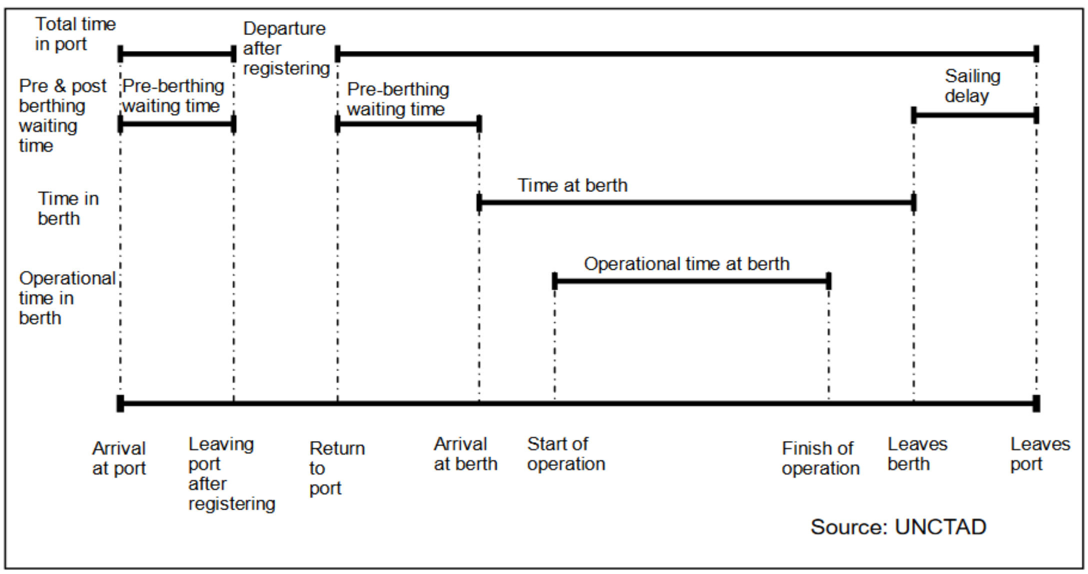

Figure 4. Breakdown of ship's time in port, Source: UNCTAD.

As the tanker shipping routes have become increasingly longer. Therefore, the turnaround Timing of the tankers has also become longer.

The average turnaround time of ships is a key parameter to measure a port's efficiency, this was reduced by 25 per cent to 64.4 hours in 2017-18 from 87.3 hours in 2015-16 in Indian ports.

The higher efficiency and productivity had translated into the net profit of major ports increasing by nearly 75 % to ₹3,414 crore (455887709.65 USD) between financial years 2016-17 and 2017-18 (The Hindu BusinessLine, 2018)

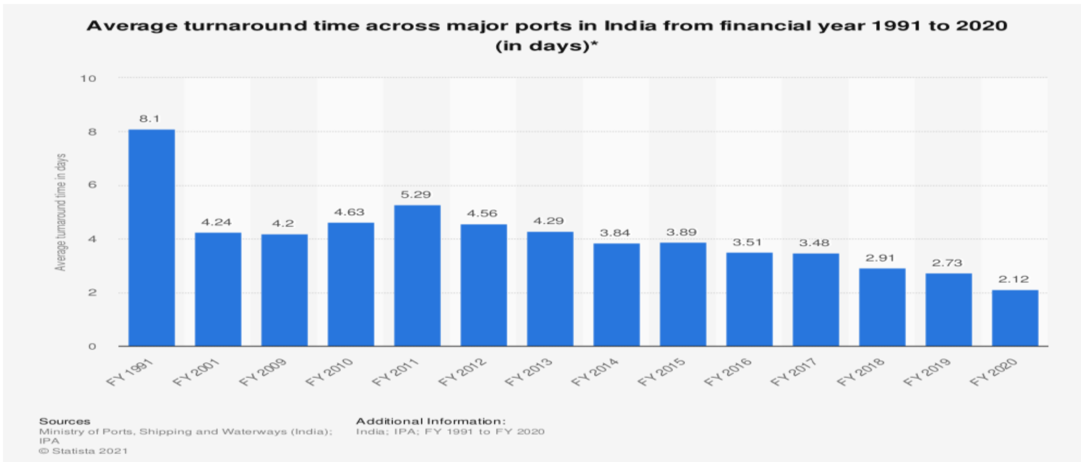

Figure 5. Average turnaround time across major ports in India 1991-2020, Source- Statista.

It is important to understand the time and cost of bunkering (fueling of the ship) since this parameter is vital to determine the turnaround cost. Turnaround cost is proportional to the turnaround timing. This means if the turnaround cost can be saved by minimizing cost and time in operation such as bunkering, we can reduce the turnaround timing, hence increasing the efficiency.

According to (ISO, 2021) cost savings for bunkering operations account for an estimated 66 % to 76 % of total savings, with the remainder attributed to reductions in the number of disputes that arose, as well as the time needed to resolve disputes when they do occur. Turnarounds can also be improved by improving the turnaround management which includes many management functions like ship selection, crew-training, planning, scheduling, and control etc. Turnover time for each function must also be determined. Notwithstanding anything to the contrary contained by the other authors with respect to turnaround parameters, all the turnaround parameters will be considered as training data to better visualize the impact of managing with the turnaround profitability from the tanker ship operations which means all the features that will lead to the increase in efficiency at port and fast movement will be used as a training data for the machine learning model for this purpose. This will give a clear picture of which variable has a higher importance & also turnaround patterns for a particular port can be predicted which will help ship owners & managers to fix their ships on a better route and at better charter price making smarter decisions.

2.7 Time Charter Price fluctuations

According to the Moore Stephens Maritime index for a VLCC (Very Large Crude Carrier- class of Oil tanker ship) of deadweight (ships weight carrying capacity- Cargo+ Fuel+ Fresh water + Ballast water (for ship stability + provisions + passengers and crew) & excluding the weight of the empty ship) ranging between 180,000 DWT to 319,999 DWT the Total OPEX (Operating Expense) per day would cost around $10,566 USD per day whereas the TCE-Time Charter Equivalent price at ship might be hired by charterer from the ship owner would range between $27316 to $43491 USD for the average age of VLCC- Oil tanker ship close to 10 years as mentioned in the below table Figure 6 (Moore Stephens S.A, 2020)

VLCC (180,000 – 319,999 dwt)

Daily KPIs	TCE	Crew Wages	Provisions	Crew Other	Lubricants	Stores	R & M	Spares	Insurance costs	Admin	Total Opex*
Observations	55	56	56	56	56	56	56	54	56	56	56
Average	$35,362	$4,131	$272	$502	$478	$448	$395	$837	$685	$1,247	$8,966
Lower bound	$27,316	$3,705	$234	$292	$356	$320	$198	$471	$553	$784	$7,727
Higher bound	$43,491	$4,734	$306	$816	$583	$569	$479	$1,079	$875	$1,378	$10,566
Age (AVG)	9.85	9.91	9.91	9.91	9.91	9.91	9.91	9.76	9.91	9.91	9.91

Figure 6. Moore Maritime Index 2020, Tankers – V.L.C.C KPI & Cost index.

Worldscale is another factor considered for fixing the charter price for the given Oil tanker's cargo which is a unified system of establishing payment of freight rate (Clarkson's Research's, n.d.).

As per the Clarkson's Research's Shipping Intelligence weekly publication for the year 2017 states the Floor rate and Cap rate for the VLCC ship charter hire. The charter hire under the contract is linked to one year time charter rates for 310,000 DWT and 150,000 DWT ships, the market rate shall be averaged out considering all weekly publications during the preceding year from January 1 to December 31 to arrive to base charter hire prices for the following year. Considering for the following year works out to be $18,601 per day and the agreed premium is 10 per cent, the charter-hire payable to owners during 2018 shall be 18,601 + 10% = $20,461 per day (Cap rate). Assuming it to be discount, the payable charter-hire during 2018 shall be 18,601-10% = $16,741 per day (Floor rate). If agreed premium works out to be less than the floor rate, the charter hire payable will be the floor rate & if the premium works out to be more than the cap rate, then the payable charter hire shall be the Cap rate Cap rate (Clarkson's Research, 2017; The Hindu BusinessLine, 2018).

With such a stringent Cap and floor rates it would be tough for the ship owners to squeeze profits. This brings the question of the commercial aspect of the shipping industry whereas the operations are concerned when it comes to long delays at anchorage, ships waiting for a long time for the berthing prospects wherein after tendering N.O.R (Notice of Readiness) and ship is ready in all aspects to discharge its cargo, especially this happens in the case of tanker ships. There are lot of ports across the globe which handle a huge volume of ships anchored at their anchorage waiting area for the berths during too heavy congestion. This delay leads to financial losses for interested parties concerned over the cargo being carried by a vessel which no owners indeed would ever like to accept and for unforeseen circumstances, these losses must be borne which in terms of financial loss is very significant amount, and this especially effect the small shipping owners with less or even maybe older ships & when we look at this problem of financial lose and compare it with Moore Maritime index.

Total OPEX (Operating Expense) for the VLCC ship around $10566 USD a day (Moore Stephens S.A, 2020), assuming the fact if the ship owners bare any lose in Charter hiring money, he would sometimes not even make any profits and what if as the ships grow old the operating price will also increase and again in turn the financial lose in any aspect can make ship-owners face the downfall. It's not only about the financial losses but delays also effect the entire supply chain & humanity. There are many issues modern shipping industry is facing such as Decarbonization of shipping, new environmental regulations, global economic crisis, increase in fuel prices and the list goes on.

2.8 Summary

Previous studies in the maritime and tanker shipping sectors have highlighted a range of ongoing challenges and emerging solutions. Research has identified existing operational inefficiencies, where fluctuating charter rates and logistical constraints impact profitability. Literature also addresses the impact of COVID-19, which has intensified operational hurdles, from crew transitions to supply chain disruptions, with studies outlining both immediate and long-term economic effects.

Further literature examines international political influences on the tanker market, showing how geopolitical shifts, including sanctions and trade policies, impact tanker routes and profitability. Financial strain from overcapacity in tanker fleets has been explored, with discussions on how economic downturns and capacity imbalances affect operational margins. Additionally, research has emphasized the need for efficient turnaround times, where reducing delays and optimizing port operations are seen as critical for competitive advantage.

A more recent focus is on the financial strategy of sales-and-leaseback models as a way for shipowners to enhance cash flow and manage compliance costs amidst rising regulatory demands. This approach is studied for its potential to provide liquidity while retaining operational control, similar to applications in other industries.

Although prior studies provide useful insights into these challenges, there remains a significant gap in the direct application of AI, ML, and NLP for addressing these issues, especially in the areas of decision-making and predictive analysis. This research intends to fill that gap by examining how AI/ML can be applied to streamline chartering processes, enhance turnaround efficiency, and aid in meeting regulatory standards.

By leveraging these technologies and integrating financial models like sales-and-leaseback, this study seeks to offer data-driven, sustainable solutions to enhance operational efficiency and financial resilience in the tanker shipping industry.

CHAPTER III

METHODOLOGY

3.1 Overview of the Research Problem

The tanker shipping industry faces a critical need to enhance decision-making efficiency in an era marked by intense market volatility, stringent regulatory requirements, and rapidly evolving environmental demands. Key challenges, including port congestion, fluctuating freight rates, and geopolitical factors, place immense pressure on ship owners and managers to make informed, data-driven decisions. Conventional practices, which rely heavily on historical trends and personal expertise, often fall short of optimizing operational efficiency in today's dynamic environment. This underscores the urgency for a data-driven approach that leverages advanced technologies such as Artificial Intelligence (AI) and Machine Learning (ML) to transform operational data into actionable insights. This research adopts a "quantitative methodology", focused on analyzing structured and unstructured data to address these operational and financial challenges.

It employs AI-ML models and survey-based insights, structured around two primary analyses:

Analysis 1: Predictive Modeling for Voyage Fixture Decisions:

This analysis leverages historical voyage data to predict key operational metrics like turnaround time and net earnings, thereby enabling ship owners to select optimal routes based on profitability and efficiency. By using robust machine learning techniques, including XGBoost and linear regression, this model forecasts turnaround and earnings with high precision, allowing for the integration of quantitative insights into operational strategies. This predictive framework enhances voyage planning by providing empirically validated recommendations tailored to sector-specific conditions.

Analysis 2: Survey Analysis for Understanding Industry Challenges and Financial Models:

In parallel, this research gathers survey data from industry professionals to assess prevailing challenges and perceptions of financial strategies, such as the sales-and-leaseback model. By analyzing Likert-scale responses, this approach captures industry sentiments on factors like regulatory compliance, market volatility, and operational costs. According to (George, 2024), Likert-scale is the Technique for the Measurement of Attitudes. The sales-and-leaseback model is examined as a financial strategy to enhance liquidity and operational flexibility. Survey responses undergo descriptive statistical analysis, providing a comprehensive view of current challenges and validating the practical relevance of AI-ML solutions within the industry.

Together, these two analyses establish a multidimensional foundation for transforming the decision-making landscape in tanker shipping. By blending quantitative model predictions with survey insights, this research offers a twofold perspective on optimizing operations and enhancing financial stability.

3.2 Operationalization of Theoretical Constructs

To ground the analyses in measurable terms, key theoretical constructs have been operationalized as follows:

1. **Voyage Fixture Decisions:** This construct pertains to the operational choices made during the chartering process, encompassing parameters such as daily charter earnings, bunker costs, sailing days, and route distance. These parameters form the input features for machine learning models, enabling the prediction of voyage profitability and efficiency.
2. **Market Dynamics and Chartering Challenges:** This construct encapsulates external market forces and internal challenges impacting tanker chartering, including regulatory compliance, technology limitations, and market fluctuations. Survey responses on these topics provide quantitative data for understanding industry-wide barriers, validating the relevance of predictive insights.

3. **<u>Sales-and-Leaseback Financial Model</u>:** This financial strategy is operationalized as a liquidity-enhancing mechanism. Survey data on perceptions of the sales-and-leaseback model are used to evaluate its role in improving competitiveness and profitability.

Table 1. Theoretical Constructs and Associated Variables in Analysis

Construct	Variable	Description	Source
Voyage Fixture Decisions	Route_Distance_nm	Distance of the route in nautical miles	Operational Data
	Daily_Charter_Party_Earnings_USD	Daily earnings from chartering	Operational Data
	Total_Gross_Earnings_USD	Calculated gross earnings for the voyage	Calculated Variable
Market Dynamics	Daily_Bunker_Cost_Sailing_Loaded_USD	Cost of bunker fuel during the loaded leg	Operational Data
	Total_Bunker_Cost_Voyage_USD	Overall bunker costs for the voyage	Calculated Variable
Sales-and-Leaseback Model	Survey Responses on Financial Preferences	Participant feedback on leaseback benefits	Survey Data
Operational Efficiency	Total_Time_A-B-A_Days	Turnaround time for the voyage	Operational Data

By operationalizing these constructs, the study effectively aligns:

- AI-ML prediction models to provide data-driven forecasts and recommendations,
- Survey insights that capture industry-wide challenges and perceptions, and
- Financial strategies to assess and optimize liquidity and competitiveness through approaches like sales-and-leaseback.

This integrated framework transforms theoretical concepts into quantifiable, actionable insights that directly support and improve decision-making in the tanker shipping industry.

3.3 Research Purpose and Questions

This research addresses three primary questions to guide the analysis, each aimed at uncovering insights into decision-making, challenges, and financial strategies in tanker shipping.

RQ.1: How do ship owners fix their ships on charters in the present day?

Aim & Background: Voyage fixture decisions represent a critical operational task within tanker shipping, involving the complex selection of routes, chartering options, and strategic choices that align with market conditions. Shipowners and managers must consider various factors such as market demand, freight rates, and operational costs to optimize each voyage's profitability and efficiency. Traditionally, these decisions have relied on personal expertise and historical data, which may limit adaptability in today's volatile market.

Rationale: This question is designed to examine the core of current decision-making practices in chartering. By investigating how shipowners and managers prioritize different factors (i.e demand trends, earnings potential, and costs), the study seeks to identify patterns in chartering decisions and how they are influenced by specific operational and market-driven considerations.

Impact: Understanding these practices will provide insights into the primary drivers of operational efficiency in tanker shipping. Data-driven approaches, including AI-ML models combined with Natural Language Processing (NLP), offer predictive analysis and actionable recommendations, making voyage planning more adaptive to real-time market fluctuations. This analysis also identifies specific areas where predictive modeling can support efficiency, enabling informed decisions in route selection and chartering.

RQ.2: What are the associated problems they face and the barriers?

Aim & Background: The tanker shipping industry is highly regulated, facing multiple challenges ranging from compliance with international maritime laws to managing fluctuating market conditions and high operational costs. Chartering involves dealing with regulatory hurdles, technology limitations, and significant market volatility, each of which can impede optimal decision-making and profitability. Industry stakeholders, including shipowners, charterers, brokers and managers, face the complex task of navigating these barriers while maintaining operational efficiency and competitiveness.

Rationale: By investigating the challenges encountered by industry professionals, this question aims to quantify and analyze the impact of these barriers on chartering practices. The survey data will provide direct insights into stakeholder perspectives on issues such as regulatory compliance, environmental considerations, and financial risks. Statistical analysis of this data will help identify common themes in stakeholder experiences and reveal potential areas where technological innovations, like AI-ML models, can address these challenges.

Impact: Identifying and understanding these challenges is essential for developing targeted solutions that improve operational resilience and compliance within the industry. By capturing the most significant barriers faced by stakeholders, this question will inform the development of tools and strategies that align with real world operational needs, ultimately supporting a more adaptable and responsive chartering process.

RQ.3: How can the sales-and-leaseback financial model be applied by ship owners and managers efficiently in the maritime industry to enhance competitiveness and profitability?

Aim & Background: Financial resilience is crucial for the long-term sustainability of tanker shipping operations, especially given the high capital costs associated with vessel ownership. The sales-and-leaseback model offers a financial strategy where ship owners can sell their vessels and lease them back, freeing up capital while retaining operational control. This model is increasingly popular as a means of enhancing liquidity, improving cash flow management, and reducing financial risk, especially in unpredictable market conditions.

Rationale: To gain insights into industry perceptions of the sales-and-leaseback model, survey responses on this topic will undergo quantitative analysis to assess the model's perceived impact on liquidity, operational control, and cash flow stability. This analysis will further explore the broader implications for financial planning and risk mitigation within the tanker shipping sector, where capital costs are substantial.

Impact: The findings will provide a framework for understanding the role of sales-and-leaseback arrangements as a tool for financial stability. By identifying how this model is perceived within the industry, the study aims to support shipowners and managers in making more informed financial decisions that strengthen their competitive position. Additionally, the insights gained from this analysis will offer guidance on integrating such financial strategies with predictive insights from AI-ML models, providing a holistic approach to both operational and financial planning.

3.4 Research Design

This study employs a quantitative research design to comprehensively address the research questions, combining machine learning modeling with survey-based analysis. The design is structured to provide data-driven insights into both operational and financial aspects of tanker shipping, thereby supporting industry stakeholders in making informed decisions.

The methodology is divided into two core components:

1. **Predictive Modeling for Operational Data**

This component uses machine learning techniques to develop predictive models for key operational metrics, such as voyage turnaround days and net earnings after operational expenditures. The modeling process follows a structured sequence to ensure relevance, accuracy, and applicability within the industry context.

Data Collection and Preprocessing:

Data Sources: The dataset comprises representative operational data, anonymized and tailored to reflect typical patterns in the tanker shipping industry. The variables include route distance, bunker costs, charter earnings, and other operational parameters relevant to the analysis. All the variables in consideration will be added in section 3.8 of this chapter.
This representative dataset simulates real world data patterns and was crafted in a controlled environment, ensuring both confidentiality and applicability to industry contexts.

Data Preprocessing: This includes normalization, outlier detection, and feature selection through correlation analysis and ANOVA. These steps refined the dataset and prepared it for model training. Also, a box plot was generated to compare **Total Gross Earnings** and **Net Earnings After OPEX** across various tanker sectors, identifying potential outliers that may reflect unusual operational factors, such as a typical voyage duration, fluctuating fuel costs, or market rates. Recognizing these outliers is essential for enhancing model accuracy by excluding anomalous data that could skew predictions, thereby ensuring a more reliable and representative analysis for optimal decision-making.

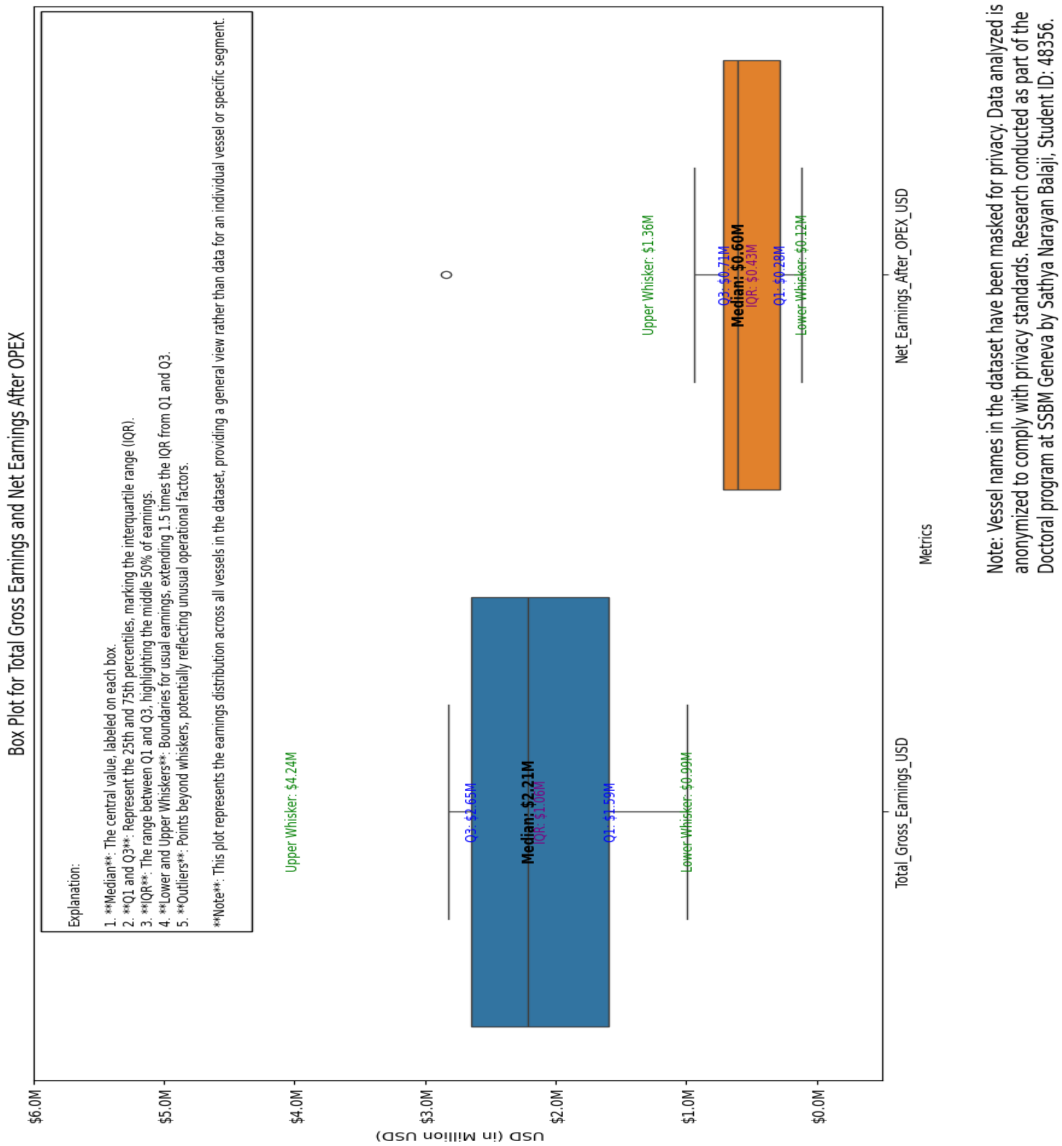

Figure 7. Box Plot for Outlier Detection- Training data

Please note from Fig 7 to Fig 10 were generated while building the ML code in Python programming.

Correlation matrix was generated for the data to identify and remove the highly collinear variables to enhance model accuracy and reliability.

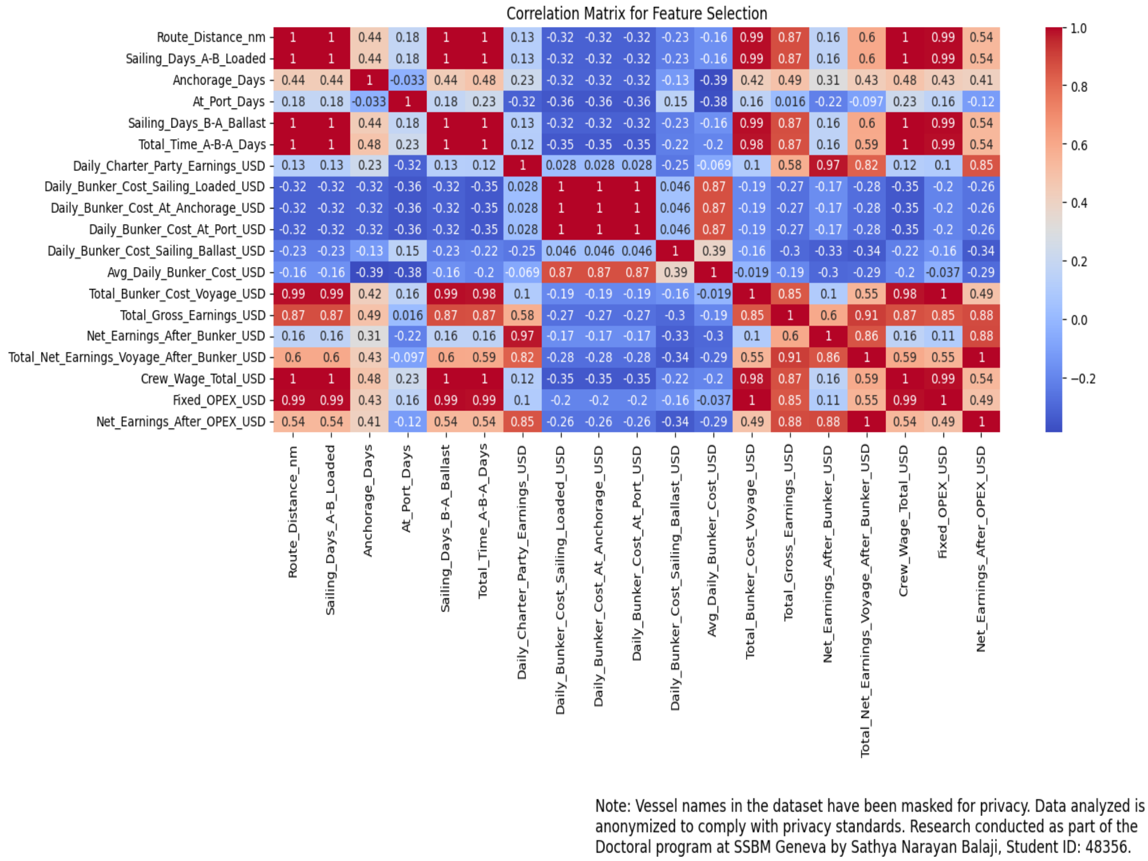

Figure 8. Correlation Matrix - Training data

<u>Feature Selection</u>:

To ensure optimal model performance and prevent overfitting, feature selection was conducted prior to model training. This process involved using correlation analysis and ANOVA tests to identify the most relevant features, thereby isolating variables that contribute significantly to predicting key operational metrics. By selecting only the most impactful variables, the study enhances model efficiency and interpretability, laying a strong foundation for subsequent algorithm selection and training.

ANOVA Results for Total Time A-B-A Days:

	p-value
Avg_Daily_Bunker_Cost_USD	4.773798e-62
Daily_Bunker_Cost_Sailing_Ballast_USD	2.298849e-57
Daily_Bunker_Cost_Sailing_Loaded_USD	7.857704e-52
Daily_Bunker_Cost_At_Port_USD	9.092605e-52
Daily_Bunker_Cost_At_Anchorage_USD	9.442897e-52
Daily_Charter_Party_Earnings_USD	8.930253e-30
Crew_Wage_Total_USD	1.828546e-19
Fixed_OPEX_USD	3.755257e-19
Total_Bunker_Cost_Voyage_USD	4.166311e-19
At_Port_Days	1.234406e-18
Anchorage_Days	1.267420e-18
Route_Distance_nm	1.165591e-17
Net_Earnings_After_Bunker_USD	8.681342e-13
Total_Gross_Earnings_USD	8.376035e-12
Sailing_Days_B-A_Ballast	1.103395e-09
Sailing_Days_A-B_Loaded	4.640435e-08
Net_Earnings_After_OPEX_USD	9.559072e-06

ANOVA Results for Total Net Earnings After Bunker:

	p-value
At_Port_Days	0.000001
Anchorage_Days	0.000001
Sailing_Days_B-A_Ballast	0.000001
Sailing_Days_A-B_Loaded	0.000001
Route_Distance_nm	0.000002
Daily_Bunker_Cost_At_Anchorage_USD	0.000002
Daily_Bunker_Cost_At_Port_USD	0.000002
Net_Earnings_After_Bunker_USD	0.000002
Daily_Bunker_Cost_Sailing_Ballast_USD	0.000002
Avg_Daily_Bunker_Cost_USD	0.000002
Daily_Bunker_Cost_Sailing_Loaded_USD	0.000003
Daily_Charter_Party_Earnings_USD	0.000004
Crew_Wage_Total_USD	0.000021
Total_Gross_Earnings_USD	0.000115
Fixed_OPEX_USD	0.022195
Total_Bunker_Cost_Voyage_USD	0.089773
Net_Earnings_After_OPEX_USD	0.577005

Figure 9. ANOVA Results for Feature Selection

Model Selection and Training:

Algorithm Selection: The study uses XGBoost and Linear Regression models, tested for their predictive capability across different operational metrics. Below is Model evaluation summary whilst comparing both the models based on their performances.

- **Dataset:** Analysis performed on significant features based on correlation analysis.
- **Criteria:** Models evaluated based on MSE and R^2 scores with the following thresholds:
- **MSE Threshold for XGBoost preference:** 10%
- **R^2 Threshold for XGBoost preference:** 5%

Below is the detailed Model evaluation summary based on which XGBoost model was used for model building.

```
Model Evaluation Summary
Date: September 30, 2024
Dataset: Analysis performed on significant features based on correlation analysis.
Criteria: Models evaluated based on MSE and R² scores with the following thresholds:
- MSE Threshold for XGBoost preference: 10%
- R² Threshold for XGBoost preference: 5%

Evaluation Results for Total_Time_A-B-A_Days:
Linear Regression - MSE: 0.0135, R² Score: 0.9999
XGBoost - MSE: 9.1986, R² Score: 0.9392
Recommended Model for Total_Time_A-B-A_Days: XGBoost (close enough in MSE/R²)

Evaluation Results for Total_Net_Earnings_Voyage_After_Bunker_USD:
Linear Regression - MSE: 17.9331, R² Score: 1.0000
XGBoost - MSE: 542980285066.1419, R² Score: 0.1282
Recommended Model for Total_Net_Earnings_Voyage_After_Bunker_USD: XGBoost (close enough in MSE/R²)

--- Final Model Selection Summary ---
Best model for 'Total_Time_A-B-A_Days': XGBoost
Best model for 'Total_Net_Earnings_Voyage_After_Bunker_USD': XGBoost
```

Figure 10. Model Evaluation Summary

Model Selection Process: Based on the performance metrics, the most suitable model is selected for each operational metric. The XGBoost model is prioritized for its ability to capture non-linear relationships, while Linear Regression offers simplicity and interpretability.

Trained Model: Two prediction model were trained each for "Turnaround Prediction" & "earning Predictions" for each of the sectors [Gulf - Europe, Gulf - Japan, Caribs - Singapore, WAF - China, Gulf - S. Korea, Gulf - US Gulf, WAF - WC India, Gulf - Red Sea, WAF - US Gulf, Gulf – Singapore].

Implementation and Reporting:

Predictive Insights: Once trained, the model forecasts key metrics, supporting data-driven chartering decisions, which optimize routes based on profitability and operational efficiency.

Output Presentation: The model's outputs, such as predicted turnaround times and earnings, are formatted into actionable recommendations, suitable for integration into operational decision-making. In the working Proof of Concept (POC) code, when we select nearest port and route preferences (long or short voyages), the model generates the best route recommendation. Followed by a bar graph showcasing which sector wise potential savings in million USD.

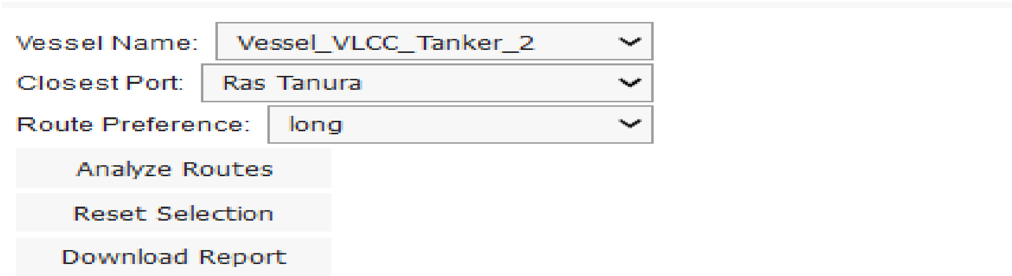

Figure 11. Prototype Interface for Vessel Route Analysis in Jupyter Notebook

Model output:

```
Report for Vessel Name: Vessel_VLCC_Tanker_2
Closest to Port: Ras Tanura
Vessel Type: VLCC crude oil tanker

Disclaimer: This AI-based analysis provides the best recommendation for your voyage fixture based on

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----------------------------------------------------------------------


Long-Term Preferred Routes:
                     Route  Turnaround_Time_Days  Earnings_per_Day_USD  Potential_Savings_USD
   Ras Tanura to Kikuma            41.858517           552300.0625             23118462.0
Ras Tanura to Rotterdam            41.510246           450204.5625             18688102.0

Short-Term Preferred Routes:
                     Route  Turnaround_Time_Days  Earnings_per_Day_USD  Potential_Savings_USD
Ras Tanura to Singapore            25.139999          323010.59375              8120486.0
     Ras Tanura to Suez            23.396053          516116.68750             12075094.0
    Ras Tanura to Yeosu            40.840370          468802.40625             19146064.0

Best Long-Term Route:
Vessel                    Vessel_VLCC_Tanker_2
Route                     Ras Tanura to Kikuma
Sector                           Gulf - Japan
Turnaround_Time_Days                 41.858517
Earnings_per_Day_USD               552300.0625
Potential_Savings_USD               23118462.0
Route_Distance_nm                       6328.0
Anchorage_Days                             2.0
At_Port_Days                               2.0

Best Short-Term Route:
Vessel                    Vessel_VLCC_Tanker_2
Route                      Ras Tanura to Yeosu
Sector                        Gulf - S.Korea
Turnaround_Time_Days                  40.84037
Earnings_per_Day_USD              468802.40625
Potential_Savings_USD               19146064.0
Route_Distance_nm                       6158.0
Anchorage_Days                             2.0
At_Port_Days                               2.0

Overall Best Route Considering Anchorage and Berth Timings:
Vessel                    Vessel_VLCC_Tanker_2
Route                     Ras Tanura to Kikuma
Sector                           Gulf - Japan
Turnaround_Time_Days                  40.86076
Earnings_per_Day_USD               545473.4375
Potential_Savings_USD               22288460.0
Route_Distance_nm                       6328.0
Anchorage_Days                             2.0
At_Port_Days                               1.0
```

Figure 12. Predicted Route Analysis and Optimal Voyage Metrics

<u>Disclaimer and Context:</u>

The results are presented as a Proof of Concept (POC) to demonstrate the model's predictive capabilities within a controlled environment. A disclaimer notes that the data is representative, anonymized, and used for academic analysis rather than live operations. This research sets a base to further develop this concept for industry wide acceptance.

<u>Relevance to RQ1 and RQ2:</u>

RQ1: This predictive modeling directly supports RQ1 by identifying key operational drivers such as market demand and costs, which influence decision-making in chartering.

RQ2: This method partially addresses RQ2 by demonstrating how predictive insights can help mitigate operational barriers, enabling efficient planning in response to fluctuating market conditions.

This structured approach leverages predictive modeling to transform historical data into actionable insights, aligning operational strategies with the industry's financial and efficiency goals.

2. Survey Based Analysis of Industry Challenges and Financial Models

This component utilizes a structured survey to gather quantitative insights into industry challenges and the relevance of financial strategies, particularly the sales-and-leaseback model. The survey analysis complements the predictive modeling by providing a real-world perspective on operational challenges and strategic considerations in tanker shipping.

Survey Data Collection and Processing

Survey Design:

A Likert-scale survey was distributed to a sample of industry professionals, asking them to rate statements about operational challenges, chartering practices, and financial strategies on a scale from 1 (Strongly Disagree), 2 (Disagree), 3 (Neutral), 4 (Agree), 5 (Strongly Agree) for all Research questions subcategorized into various sub questions for each RQ's.

Participant Anonymization:

Participant identities and company affiliations were anonymized to ensure privacy and confidentiality, with all responses treated as aggregated data.

Data Processing:

Survey responses were processed using Excel and Python programming to ensure clean, usable data. Each response was assigned a numerical score for statistical analysis.

Descriptive Statistics:

Descriptive statistics (mathematical mean, standard deviation) were calculated for each survey question, providing a quantitative summary of industry sentiments.

This analysis highlights common challenges and strategic preferences. The results for the same will be discussed in the next Chapter.

3. Integration of Predictive Modeling and Survey Analysis

Both components work in tandem to provide a comprehensive view of the tanker shipping industry's operational and financial dynamics. While the predictive model offers data driven recommendations for optimizing operational efficiency, the survey analysis brings contextual understanding of real-world challenges faced by industry professionals.

By aligning quantitative predictions with industry sentiments, this integrated design addresses the research questions in a holistic manner, supporting evidence-based, strategic decision-making within the tanker shipping sector.

3.5 Population and Sample

The sample population for this study comprises professionals with significant experience in the maritime industry, particularly in tanker shipping and marine engineering, total 17 respondents participated in the survey. Each participant has an established background in fields such as voyage management, tanker chartering, and marine data engineering. This group was selected to bring together a balanced perspective on operational decision-making, financial challenges, and technology integration within the shipping industry.

Participants were chosen based on their close association with maritime operations, allowing them to provide valuable insights into chartering practices and operational dynamics. Although this study did not involve direct engagement with shipowners, it leveraged the knowledge of professionals who work closely with them and understand the practical challenges and opportunities in this domain. This approach ensured that survey responses were informed by industry expertise, facilitating a robust analysis of current operational and financial strategies in tanker chartering in a pragmatic way.

3.6 Participant Selection

This study employed a targeted sampling approach to gather insights from professionals with substantial expertise in tanker shipping and marine engineering. Given the technical and specialized focus of this research, participants were carefully selected based on their professional roles and direct involvement in maritime operations, chartering decisions, and marine data analysis. This selection criterion was implemented to ensure that survey responses would reflect an informed perspective on the operational and financial complexities of tanker shipping.

The participants comprised marine engineers, technical and marine managers, senior data engineers, fleet management professionals, and senior technical superintendents. Each role offered a unique viewpoint on critical aspects such as voyage planning, regulatory compliance, operational costs, and financial modeling. This diversity in professional backgrounds allowed the study to capture a well-rounded understanding of tanker shipping operations, enriching the data with varied operational insights.

To align with the research objectives, individuals with extensive experience in chartering practices and decision-making processes were prioritized, particularly those who work closely with shipowners and possess a niche understanding of the market dynamics affecting tanker operations. While direct interviews with shipowners were not conducted, the selected participants offered valuable insights drawn from their close professional interactions and practical knowledge of industry practices.

This approach ensured a well-informed sample whose responses provide a robust foundation for analyzing current practices, identifying challenges, and evaluating the applicability of financial models like sales-and-leaseback in promoting competitiveness and financial resilience in tanker chartering.

3.7 Instrumentation

The study employed two main instruments to gather and analyze data:

Predictive Modeling System: The predictive modeling system, developed in Python, served as the primary tool for analyzing historical voyage data to predict key operational metrics such as turnaround days and net earnings. This system leveraged machine learning algorithms specifically XGBoost and Linear Regression to capture and forecast complex operational patterns. Key features of the predictive modeling system include:

Automated Data Preprocessing: The system integrates automated routines for data normalization and outlier detection, ensuring that data used in model training is both clean and statistically reliable.

Feature Selection Capabilities: Equipped with tools for identifying the most relevant variables, the system improves model accuracy and interpretability by focusing on essential metrics.

Evaluation Metrics: The system assesses model performance through Mean Squared Error (MSE) and R^2 scores, providing quantitative feedback on model reliability and enabling selection of the most effective predictive models.

This system ultimately produced actionable insights designed to support decision-making processes in route optimization and profitability forecasting, helping to bridge data-driven analysis with practical operational goals variables used are mentioned in Table 2.

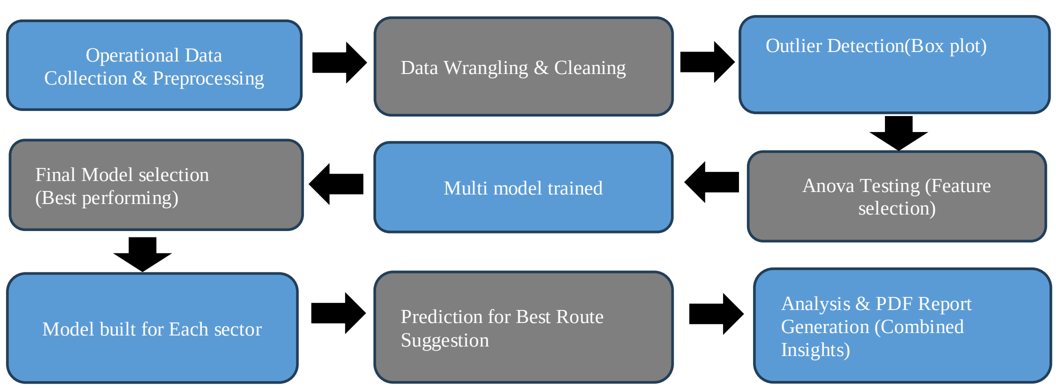


Figure 13. Flowchart of Predictive Modeling Process

Table 2. Machine Learning Model Variables and Descriptions

Variable Name	Description	Data Type
Vessel	Identifier for each vessel	Categorical
Sector	Shipping sector (e.g., Gulf - Europe)	Categorical
From_Port	Port of origin for each route	Categorical
To_Port	Destination port	Categorical
Route_Distance_nm	Distance of the route in nautical miles	Numeric
Sailing_Days_A-B_Loaded	Days required for the loaded leg of the voyage	Numeric
Anchorage_Days	Days spent at anchor	Numeric
At_Port_Days	Days spent at port	Numeric
Sailing_Days_B-A_Ballast	Days for ballast leg of the voyage	Numeric
Total_Time_A-B-A_Days	Total turnaround time for the voyage	Numeric
Daily_Charter_Party_Earnings_USD	Daily charter earnings in USD	Numeric
Daily_Bunker_Cost_Sailing_Loaded_USD	Daily bunker costs for the loaded segment	Numeric
Daily_Bunker_Cost_At_Anchorage_USD	Daily bunker cost at anchorage	Numeric
Daily_Bunker_Cost_At_Port_USD	Daily bunker cost while at port	Numeric
Daily_Bunker_Cost_Sailing_Ballast_USD	Daily bunker cost for ballast segment	Numeric
Avg_Daily_Bunker_Cost_USD	Average daily bunker cost	Numeric
Total_Bunker_Cost_Voyage_USD	Total bunker cost for the entire voyage	Numeric
Total_Gross_Earnings_USD	Gross earnings from the voyage	Numeric
Net_Earnings_After_Bunker_USD	Net earnings after deducting bunker costs	Numeric
Total_Net_Earnings_Voyage_After_Bunker_USD	Net earnings after bunker costs for the voyage	Numeric
Crew_Wage_Total_USD	Total crew wages	Numeric
Fixed_OPEX_USD	Operational expenses (OPEX) including bunker and crew costs	Numeric
Net_Earnings_After_OPEX_USD	Net earnings after OPEX	Numeric

Survey Questionnaire: A structured Likert-scale questionnaire was designed to capture industry insights on operational challenges, chartering practices, and financial strategies. The survey covered three main research questions, with sub-questions for each to obtain granular insights. The responses were collected as numerical scores, enabling statistical analysis. To maintain confidentiality, participants' identities and company affiliations were anonymized, ensuring data privacy and integrity.

The flow of survey data processing and analysis is illustrated in Figure 14, which details the sequential steps from data collection to statistical analysis.

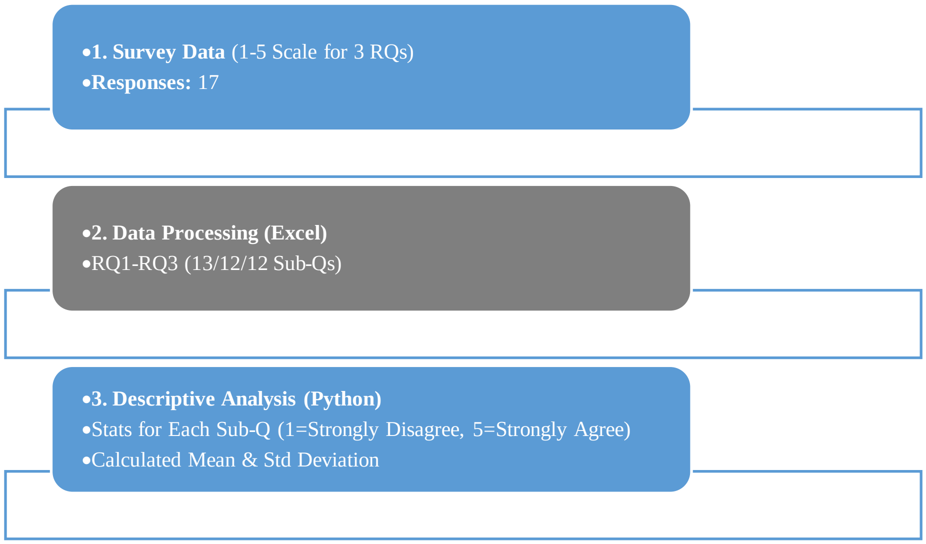


Figure 14. Flowchart of Survey Data analysis Process

3.8 Data Collection Procedures

The data collection in this study followed a structured and methodical approach due to the need for robust analysis in predictive modeling and survey-based analysis. Key aspects of the data collection process have been presented in 3.4 Research Design and 3.7 Instrumentation, where visual figures and tables helped illustrate these processes for clarity and transparency.

Operational Data Collection: The operational data, as noted in the earlier sections, was derived from anonymized and representative datasets designed to simulate real-world shipping patterns within a controlled environment.

The dataset included essential variables pertinent to tanker chartering, as outlined in Table 2, capturing key industry dynamics for a robust model training foundation.

This carefully crafted dataset ensured that the analysis reflects industry-relevant factors, while maintaining confidentiality.

Survey Data Collection: The survey, discussed in section 3.4 and 3.7, involved gathering industry insights on chartering practices, operational challenges, and financial models. Responses were anonymized to ensure data confidentiality, with all data processed for statistical reliability in Excel and Python. The sub questions for each RQ's will be represented in next chapter with Descriptive analysis.

The necessity of presenting detailed visual aids, such as the outlier detection box plot, correlation matrix, and ANOVA results in prior sections, arose from the technical complexity of the machine learning model preparation. These figures provided immediate clarity on the steps involved in data preprocessing and feature selection, supporting a precise and effective model building process.

This structured approach to data collection and processing ensured that the information used for analysis was both accurate and relevant to the research objectives. By integrating rigorous preprocessing and verification steps, including visual aids for clarity, the study establishes a reliable foundation for the predictive modeling and survey analysis that follow, ultimately supporting credible and actionable insights into tanker chartering practices.

3.9 Data Analysis

The analysis involved two parallel processes: predictive modeling for operational data and descriptive statistical analysis for survey responses which used Likert scale analysis by providing respondents with survey questionnaire.

Predictive Modeling: This analysis applied machine learning algorithms, including XGBoost and Linear Regression, to the operational data to forecast metrics such as voyage turnaround time and net earnings.

Detailed model evaluation summaries and insights were included in 3.4 Research Design, illustrating the steps of model selection and performance assessment. This analytical approach provided actionable recommendations to improve decision-making in chartering and route selection.

Descriptive Statistical Analysis of Survey Data: The survey data analysis focused on calculating descriptive statistics (mean, standard deviation) for each question. These insights, discussed in the context of industry challenges and financial strategies, validated the relevance of AI-ML models by highlighting the real-world perceptions and concerns of industry professionals. The survey analysis complements the predictive modeling outcomes by providing context-specific insights into operational and financial decision-making.

These analytical steps were thoroughly detailed in previous sections to ensure the clarity and transparency of the methodology. The results generated from these analyses will be discussed in Chapter 4.

3.10 Research Design Limitations

While this study provides a comprehensive framework for predictive modeling and survey-based insights in tanker chartering, several limitations must be noted:

Data Representation: The dataset used was representative and anonymized, created in a controlled environment to simulate real-world conditions. Although it reflects common patterns in tanker shipping, it may lack certain nuances present in live operational data.

Model Scope: The machine learning models, including XGBoost and Linear Regression, were chosen for their effectiveness in specific metrics. However, these models have limitations when applied to highly dynamic and complex real-world environments without further tuning and validation on live data.

<u>Survey Generalization</u>: The survey responses, while valuable, represent the insights of professionals in specific roles and may not entirely capture the perspectives of all industry stakeholders, particularly shipowners.

<u>Academic Scope</u>: This study serves as a Proof of Concept (POC) for academic purposes, and the results should be interpreted as such. The insights and models are intended to provide a foundation for further development and industry-wide implementation rather than immediate application.

The need for transparency and detailed visualization in 3.4 Research Design and 3.7 Instrumentation was essential to mitigate these limitations by showcasing the rigor and structure applied to data handling and model-building processes.

3.11 Conclusion

This chapter outlined the methodological framework developed to address the research questions on tanker shipping efficiency and financial resilience. Through a combination of predictive modeling and survey analysis, this study integrates data-driven insights with real-world industry perspectives, offering a well-rounded approach to tackle operational and financial challenges. The selected methods, including machine learning and structured surveys, provide a rigorous foundation for analyzing industry relevant variables, as presented in preceding sections.

While the study offers valuable insights, limitations such as data representativeness and the controlled environment for model testing emphasize that findings are preliminary and intended primarily for research purpose and exploration. These results lay a foundational base for future studies and potential industry applications, contributing a first step toward innovative, data driven decision-making in tanker shipping industry and maritime industry.

CHAPTER IV

RESULTS

This chapter presents a comprehensive analysis of the data collected to address each of the study's three research questions, focusing on the critical factors that influence decision-making in the tanker shipping industry, the challenges faced by industry professionals, and the applicability of financial models like the sales-and-leaseback approach. The analysis in this chapter builds directly upon the data preprocessing, feature selection, and predictive modeling efforts outlined in Chapter 3, utilizing a structured approach that ensures consistency between the methodology and the results.

Each research question is examined independently, beginning with descriptive statistics derived from Likert-scale survey responses, which highlight the primary trends and sentiments among industry professionals. This is followed by a thorough analysis of each question, exploring how variables identified in the data preparation and modeling stages, such as market demand, operational costs, and regulatory pressures, impact strategic decision-making and financial stability within the industry. By isolating each question, this chapter provides a focused view of the factors influencing tanker chartering practices, the operational barriers encountered, and the relevance of financial models in mitigating risk and enhancing flexibility.

The findings in this chapter are enriched by the predictive modeling conducted in Chapter 3, where machine learning techniques, including XGBoost and Linear Regression, were applied to operational data to forecast key metrics such as voyage turnaround times and net earnings after operational expenses. These models serve as an analytical backbone to support data driven decision-making, providing empirical evidence on the relationships between various operational factors and their impact on profitability. For instance, the model’s predictions inform the analysis of chartering decisions in response to fluctuating market conditions, offering insights into how operational strategies can be optimized for efficiency and profitability. By integrating these predictive insights with the survey data, the analysis achieves a multidimensional perspective, revealing not only what industry professionals prioritize but also how data driven models can support these priorities in practice.

Additionally, this chapter includes the results of feature selection methods, such as correlation analysis and ANOVA, which helped isolate the most significant variables for model training. These variables are directly reflected in the survey questions and analyses presented here, underscoring their practical relevance to the industry's operational context. By aligning the variables used in the predictive models with the themes emerging from the survey responses, the chapter reinforces the importance of these factors in shaping the industry’s decision-making processes. The findings highlight how data driven models, combined with industry insights, provide a robust foundation for addressing challenges like market volatility, regulatory compliance, and economic downturns.

In summary, this chapter bridges the quantitative insights generated through predictive modeling with the qualitative insights captured from survey responses. This integrated approach provides a holistic understanding of the tanker shipping industry’s operational and financial landscape, offering actionable recommendations for stakeholders. By connecting the results to the modeling efforts and data processing techniques detailed in Chapter 3, the chapter illustrates the value of combining empirical data analysis with predictive modeling to inform strategic decision making. This combination not only enhances academic understanding but also serves as a practical guide for industry professionals navigating complex regulatory and market environments.

4.1 Research Question One

RQ.1: How do ship owners fix their ships on charters at present day?

The first research question explores the key factors that influence chartering decisions within the tanker shipping industry. This analysis utilizes descriptive statistics derived from a Likert-scale survey that captures respondent’s views on various aspects of chartering practices. Each sub-question within the Likert data provides insight into the weight and priority given to different decision-making elements by industry professionals.

The analysis highlights the relative importance of operational, market-driven, and strategic factors that impact chartering decisions.

Table 3. Descriptive Statistics for RQ1

	N	Min	Max	Mean	Std. dev
I rely heavily on market demand when deciding to charter my ships	17	3	5	4.00	0.79
Operational costs are a primary factor in my decision-making process for chartering	17	5	5	5.00	0.00
I prefer long-term charters over short-term agreements	17	3	5	3.94	0.66
The reputation of the charterer significantly influences my decision to enter a contract	17	4	5	4.65	0.49
I primarily use brokers to find potential charterers	17	3	5	4.41	0.71
Online platforms have become an essential tool in my chartering process	17	3	5	3.82	0.53
I prioritize charter rates when negotiating terms with potential charterers	17	4	5	4.53	0.51
Assessing the creditworthiness of charterers is a crucial step in my decision-making process	17	4	5	4.82	0.39
I believe there is an increasing demand for eco-friendly ships in the charter market	17	4	5	4.47	0.51
The COVID-19 pandemic has changed my approach to chartering practices	17	3	5	4.29	0.59
I foresee sustainability pressures influencing future charter agreements	17	1	5	3.12	1.36
I am satisfied with the current technologies available for ship chartering	17	3	4	3.71	0.47
Flexibility in charter agreements is more important to me now than it was five years ago	17	4	5	4.76	0.44

The responses reveal that market demand and operational costs are highly influential in chartering decisions. Below is a detailed examination of each sub-question, accompanied by the statistical measures (mathematical mean, standard deviation, and min-max values) that illustrate the consistency and variability in responses.

1. **I rely heavily on market demand when deciding to charter my ships:**

   Mean = 4.00, **Std dev** = 0.79

   The responses suggest that market demand significantly influences chartering decisions, with a mean of 4.00, indicating strong agreement among respondents. The standard deviation of 0.79 shows moderate variability, suggesting some level of individual difference in reliance on market trends, though overall agreement is high.

2. **Operational costs are a primary factor in my decision-making process for chartering:**

   Mean = 5.00, **Std dev**= 0.00

   Operational costs are unanimously viewed as a primary factor, with a perfect mean of 5.00 and no variability (standard deviation of 0.00). This response indicates that all participants agree that controlling operational expenses is a crucial consideration when chartering ships, underscoring its universal importance.

3. **I prefer long-term charters over short-term agreements:**

   Mean = 3.94, **Std dev** = 0.66

   With a mean of 3.94, responses show a slight preference for long-term charters, though opinions vary slightly (standard deviation = 0.66). This preference reflects a strategic inclination toward stable, long-term agreements, which may offer more financial security and operational predictability.

4. **The reputation of the charterer significantly influences my decision to enter a contract: Mean** = 4.65, **Std dev**= 0.49

   The high mean score of 4.65 and low standard deviation = 0.49 suggest that the reputation of charterers is a critical factor, with most respondents agreeing strongly. This reflects the importance of trust and reliability in contractual partnerships, which can mitigate risks associated with payment reliability and operational efficiency.

5. **I primarily use brokers to find potential charterers**:

   Mean = 4.41, **Std dev** = 0.71

   Brokers play an essential role in the chartering process, as indicated by a mean of 4.41. The standard deviation of 0.71 shows some variation, indicating that while brokers are commonly used, some respondents may also rely on alternative channels for sourcing charterers.

6. **Online platforms have become an essential tool in my chartering process**:

   Mean = 3.82, **Std dev** = 0.53

   The mean score of 3.82 indicates moderate agreement regarding the importance of online platforms in chartering. With a standard deviation of 0.53, the responses show relatively low variability, suggesting that digital platforms are gaining traction but may not yet be universally adopted as the primary tool for chartering.

7. **I prioritize charter rates when negotiating terms with potential charterers:**

   Mean = 4.53, **Std dev** = 0.51

   Charter rates are a high priority during negotiations, as shown by a mean of 4.53. The low standard deviation (0.51) suggests a strong consensus on the importance of securing favorable rates, aligning with the financial objectives of maximizing revenue.

8. **Assessing the creditworthiness of charterers is a crucial step in my decision-making process**:

   Mean = 4.82, **Std dev**= 0.39

   The mean score of 4.82 highlights the importance of credit assessments, with minimal variability (Std = 0.39) among respondents. This suggests that financial reliability of charterers is almost universally prioritized to mitigate risks associated with payment defaults.

9. **I believe there is an increasing demand for eco-friendly ships in the charter market:**

   Mean = 4.47, **Std dev**= 0.51

   Respondents largely agree on the growing demand for eco-friendly vessels, with a mean of 4.47 and standard deviation of 0.51. This trend aligns with global environmental shifts and regulatory pressures, indicating that sustainability is increasingly influencing chartering preferences.

10. **The COVID-19 pandemic has changed my approach to chartering practices: Mean** = 4.29, **Std** d**ev**= 0.59

    The pandemic's impact on chartering practices is reflected in a mean score of 4.29, with some variation (Std = 0.59). This highlights the need for adaptive strategies in response to unprecedented global disruptions, as industry professionals adjust to new operational realities.

11. **I foresee sustainability pressures influencing future charter agreements:**

    Mean = 3.12, **Std dev** = 1.36

    With a mean of 3.12 and a relatively high standard deviation (1.36), responses are mixed regarding the future impact of sustainability pressures. This suggests that while some respondents anticipate greater sustainability requirements, others may feel that such pressures are less immediate.

12. **I am satisfied with the current technologies available for ship chartering:**

    Mean = 3.71, **Std dev** = 0.47

    The mean score of 3.71 indicates moderate satisfaction with available technologies, with low variability (Std = 0.47). This points to a general acceptance of current technological tools but suggests room for further innovation and improvement.

13. **Flexibility in charter agreements is more important to me now than it was five years ago: Mean** = 4.76, **Std dev** = 0.44

    The mean score of 4.76 reflects a strong agreement on the growing importance of flexibility in charter agreements, with low variability (Std = 0.44).

    This shift underscores the industry's response to volatile markets and the need for adaptive contractual arrangements.

Summary of RQ1 analysis.

The descriptive statistics for RQ1 provide a fine understanding of the factors influencing chartering decisions in the tanker shipping industry. Operational costs, creditworthiness of charterers, and flexibility in agreements emerge as critical priorities, indicating the industry's focus on financial stability, risk mitigation, and adaptability. The findings also underscore a growing emphasis on sustainability and technological adaptation, reflecting broader shifts in regulatory and market expectations. These insights align closely with the variables identified in predictive modeling efforts, reinforcing the relevance of these factors for strategic decision-making in the industry.

4.2 Research Question Two

RQ.2: What are the associated problems they face and the barriers?

The second research question addresses the critical barriers and challenges that shipowners encounter in the chartering process, which complicate decision-making and operational efficiency.

Table 4. Descriptive Statistics for RQ2

	N	Min	Max	Mean	Std. dev
Fluctuating market conditions make it difficult to secure profitable charter agreements	17	4	5	4.88	0.33
Regulatory compliance is a significant barrier in the chartering process	17	4	5	4.69	0.48
The lack of transparency from charterers leads to challenges in negotiation	17	4	5	4.59	0.51
Finding reliable and creditworthy charterers is increasingly difficult	17	3	5	4.59	0.62
The need for eco-friendly practices adds complexity to the chartering process	17	4	5	4.35	0.49
Insufficient technology solutions hinder effective chartering operations	17	4	5	4.47	0.51
Short-term charter agreements are often less financially viable than expected	17	4	5	4.47	0.51
There is a lack of skilled personnel to manage chartering negotiations effectively	17	4	5	4.56	0.51
Legal disputes with charterers are a common issue that complicates the chartering process	17	4	5	4.41	0.51
Economic downturns significantly impact my ability to charter ships successfully	17	4	5	4.82	0.39
The complexity of contracts makes it difficult to understand obligations and risks	17	4	5	4.76	0.44
Geopolitical factors create uncertainty in the charter market	17	4	5	4.82	0.39

This section utilizes descriptive statistics from a Likert-scale survey to provide an in-depth analysis of the factors that industry professionals consider as impediments to successful chartering. The analysis of each sub-question highlights the magnitude of these barriers, with a focus on issues such as fluctuating market conditions, regulatory compliance, transparency challenges, and geopolitical factors.

The responses reveal that market volatility, regulatory hurdles, and economic downturns are among the most significant barriers, according to industry feedback. This emphasis underscores the complexities shipowners face in navigating external pressures and adapting to a dynamic chartering environment. Below, a detailed examination of each sub question is presented, supported by statistical measures including mean scores, standard deviations, and minimum maximum values, which provide insights into the consistency and variability of responses.

1. **Fluctuating market conditions make it difficult to secure profitable charter agreements:**

   Mean = 4.88, **Std Dev** = 0.33

   The high mean score of 4.88 reflects a strong consensus that market volatility is a significant barrier to profitable chartering. The low standard deviation (0.33) suggests that this perception is consistent across respondents, highlighting the impact of unpredictable market conditions on chartering profitability.

2. **Regulatory compliance is a significant barrier in the chartering process:**

   Mean = 4.69, **Std Dev** = 0.48

   A mean of 4.69 underscores the importance of regulatory compliance as a challenging factor, with moderate variability (Std Dev = 0.48). This indicates that regulatory demands are perceived as a substantial burden that shipowners must navigate, often increasing operational complexity and cost.

3. **The lack of transparency from charterers leads to challenges in negotiation:**

   Mean = 4.59, **Std Dev** = 0.51

   A mean score of 4.59 reveals that transparency issues are a considerable challenge during negotiations, with some variability in responses (Std Dev = 0.51).

This indicates a perception of distrust or insufficient openness from charterers, which complicates the process of reaching equitable agreements.

4. **Finding reliable and creditworthy charterers is increasingly difficult:**

   Mean = 4.59, **Std Dev** = 0.62

   The mean score of 4.59, coupled with a higher standard deviation (0.62), suggests that while the challenge of finding trustworthy charterers is broadly recognized, there is some variability in how respondents perceive this issue.

5. **The need for eco-friendly practices adds complexity to the chartering process:**

   Mean = 4.35, **Std Dev** = 0.49

   With a mean of 4.35, respondents acknowledge that environmental expectations add a layer of complexity, particularly as sustainability becomes a priority. The moderate variability (Std Dev = 0.49) suggests differing levels of adaptation among shipowners to these eco-friendly practices.

6. **Insufficient technology solutions hinder effective chartering operations:**

   Mean = 4.47, **Std Dev** = 0.51

   A mean of 4.47 highlights that technological limitations are seen as a hindrance to optimal operations. Variability in responses (Std Dev = 0.51) suggests a divergence in technological adaptation and reliance on digital tools across the industry.

7. **Short-term charter agreements are often less financially viable than expected:**

   Mean = 4.47, **Std Dev** = 0.51

   This mean score of 4.47 suggests that short-term agreements may not yield expected financial returns, aligning with the industry's preference for longer-term, more stable contracts.

8. **There is a lack of skilled personnel to manage chartering negotiations effectively:**

   Mean = 4.56**, Std Dev** = 0.51

   The mean score of 4.56 emphasizes the perceived need for skilled personnel in chartering, indicating a significant barrier related to workforce capabilities.

9. **Legal disputes with charterers are a common issue that complicates the chartering process:**

   Mean = 4.41, **Std Dev** = 0.51

   With a mean of 4.41, legal complications are identified as a persistent barrier, suggesting that disputes are not uncommon and add strain to chartering efforts.

10. **Economic downturns significantly impact my ability to charter ships successfully:**

    Mean = 4.82, **Std Dev** = 0.39

    A mean score of 4.82 reflects strong agreement that economic downturns negatively Impact chartering, with low variability (Std Dev = 0.39), indicating consensus on the adverse effects of economic fluctuations.

11. **The complexity of contracts makes it difficult to understand obligations and risks:**

    Mean = 4.76, **Std Dev** = 0.44

    The high mean of 4.76 suggests that contract complexity poses a considerable challenge, complicating the understanding of obligations and associated risks.

12. **Geopolitical factors create uncertainty in the charter market:**

    Mean = 4.82, **Std Dev** = 0.39

    A mean score of 4.82, with low standard deviation, indicates strong agreement that geopolitical instability adds significant uncertainty to chartering decisions, aligning with global concerns over political and economic volatility.

Summary of RQ2 Analysis

The findings for RQ2 demonstrate that external factors such as market volatility, regulatory demands, and geopolitical instability are perceived as substantial barriers, indicating a challenging environment for shipowners. Economic downturns and contract complexity also highlight the unpredictability and risks inherent in chartering operations. These insights align closely with the broader strategic challenges in the industry, where adaptive measures, robust regulatory compliance, and skilled personnel are essential for overcoming operational barriers. By understanding these challenges, shipowners can better navigate the complexities of chartering, underscoring the need for industry-wide resilience strategies.

4.3 Research Question Three

RQ.3: How can the Sales-and-leaseback financial model be applied by ship owners and managers efficiently in the maritime industry to become competitive and generate more profits?

The third research question delves into the application of the sales-and-leaseback financial model within the maritime industry, focusing on its potential to improve competitiveness and profitability for ship owners and managers. The analysis of responses from industry professionals, captured through a Likert-scale survey, provides insights into the perceived advantages and challenges of this model. This section presents a detailed examination of each sub-question, supported by descriptive statistics including the mean, standard deviation, and minimum-maximum values, to understand the variability and consistency in perceptions of this financial model.

Table 5. Descriptive Statistics for RQ3

	N	Min	Max	Mean	Std. dev
The sales-and-leaseback model provides significant capital for reinvestment in operations	17	4	5	4.82	0.39
This model allows for improved liquidity and financial flexibility in my organization	17	4	5	4.82	0.39
Sales-and-leaseback arrangements can help mitigate risks associated with ship ownership	17	3	5	4.11	0.47
Implementing this model enhances my company’s competitive position in the market.	17	4	5	4.88	0.33
The predictability of lease payments simplifies cash flow management	17	5	5	5.00	0.00
This model enables me to maintain operational control over the ships while freeing up capital	17	4	5	4.59	0.51
Sales-and-leaseback transactions are straightforward and easy to negotiate	17	4	6	4.47	0.62

There are significant tax advantages to utilizing the sales-and-leaseback model	17	4	5	4.35	0.49
The long-term nature of lease agreements can complicate financial planning	17	3	5	4.12	0.78
My organization has successfully implemented sales-and-leaseback arrangements in the past	17	1	5	2.41	0.94
The model provides a buffer against market volatility for my shipping operations	17	3	5	4.29	0.59
I believe that the sales-and-leaseback model can lead to increased profitability	17	4	5	4.82	0.39
Valid N (listwise)	17	4	5	4.82	0.39

1. **The sales-and-leaseback model provides significant capital for reinvestment in operations:**

   Mean = 4.82, **Std Dev** = 0.39

   The high mean score of 4.82 indicates strong agreement on the model's ability to generate substantial capital for reinvestment. This consensus, with low variability (Std Dev = 0.39), reflects a widely shared belief that the model can play a crucial role in financing operational growth and improvement.

2. **This model allows for improved liquidity and financial flexibility in my organization:**

   Mean = 4.82, **Std Dev** = 0.39

   Similar to capital reinvestment, the mean score of 4.82 highlights a shared perception that sales-and-leaseback enhances liquidity and financial adaptability. The low standard deviation underscores consistent agreement among respondents about the model's flexibility benefits.

3. **Sales-and-leaseback arrangements can help mitigate risks associated with ship ownership:**

   Mean = 4.11, **Std Dev** = 0.47

The mean score of 4.11 suggests that respondents view sales-and-leaseback as a potential risk management tool, although the moderate variability indicates mixed views on its effectiveness in this regard.

4. **Implementing this model enhances my company's competitive position in the market:**

   Mean = 4.88, **Std Dev** = 0.33

   A mean score of 4.88 with low variability (Std Dev = 0.33) indicates a strong consensus that the model strengthens competitive positioning, suggesting that companies using sales-and-leaseback are perceived as better equipped to maintain or enhance their market standing.

5. **The predictability of lease payments simplifies cash flow management:**

   Mean = 5.00, **Std Dev** = 0.00

   With a perfect mean score of 5.00 and zero variability, this result reveals unanimous agreement that predictable lease payments facilitate smoother cash flow management, reflecting one of the most valued aspects of the sales-and-leaseback model.

6. **This model enables me to maintain operational control over the ships while freeing up capital:**

   Mean = 4.59, **Std Dev** = 0.51

   A mean score of 4.59 highlights the model's perceived ability to strike a balance between capital flexibility and operational control, albeit with moderate variability, suggesting differing levels of operational reliance on this model.

7. **Sales-and-leaseback transactions are straightforward and easy to negotiate:**

   Mean = 4.47, **Std Dev** = 0.62

   The mean score of 4.47 suggests that respondents generally find sales-and-leaseback arrangements easy to negotiate, though some variability indicates that experiences may differ based on specific transaction contexts.

8. **There are significant tax advantages to utilizing the sales-and-leaseback model:**
   Mean = 4.35, **Std Dev** = 0.49
   With a mean score of 4.35, respondents recognize the model's tax benefits, with low variability indicating a consensus on its fiscal advantages.
9. **The long-term nature of lease agreements can complicate financial planning:**
   Mean = 4.12, **Std Dev** = 0.78
   While the mean of 4.12 suggests that respondents acknowledge potential challenges in long-term financial planning, the higher standard deviation reflects more diverse opinions on this aspect of sales-and-leaseback.
10. **My organization has successfully implemented sales-and-leaseback arrangements in the past:**
    Mean = 2.41, **Std Dev** = 0.94
    The low mean score of 2.41 indicates limited prior experience with the model among respondents, with high variability suggesting differing levels of familiarity or historical usage across organizations.
11. **The model provides a buffer against market volatility for my shipping operations:**
    Mean = 4.29, **Std Dev** = 0.59
    A mean of 4.29 shows moderate agreement on the model's role as a buffer against market volatility, though some variability indicates varied perceptions of its effectiveness in stabilizing operations amid market fluctuations.
12. **I believe that the sales-and-leaseback model can lead to increased profitability:**
    Mean = 4.82, **Std Dev** = 0.39.
    With a high mean of 4.82, respondents widely perceive the model as a pathway to improved profitability, supporting the view that sales-and-leaseback can enhance financial outcomes.

Summary of RQ3 Analysis

The analysis of RQ3 indicates that industry professionals generally view the sales-and-leaseback model as an advantageous financial strategy, particularly for improving liquidity, enhancing competitiveness, and providing financial stability through predictable lease payments. While respondents recognize its benefits, such as tax advantages and ease of negotiation, there are also concerns about its potential complications in long-term financial planning. Furthermore, limited past implementation experience among respondent's points to a need for broader adoption and understanding of the model's practical applications.

In alignment with predictive modeling efforts, the findings suggest that sales-and-leaseback can be strategically leveraged to enhance competitiveness and profitability. However, the variability in responses regarding risk mitigation and long-term implications highlights that successful implementation requires careful planning, industry expertise, and adaptability. The consensus on profitability and cash flow management reinforces the model's potential to act as a valuable tool for shipowners seeking financial resilience and flexibility in the volatile maritime sector.

4.4 Summary of Findings

This section integrates the results from the analysis of each research question, combining insights from descriptive statistics, predictive modeling, and survey responses. The findings highlight key trends within the tanker shipping industry, focusing on factors influencing chartering decisions, operational challenges, and the potential of financial models like sales-and-leaseback to improve strategic positioning and profitability. By merging quantitative insights from machine learning models with qualitative data from industry professionals, this chapter provides a layered view of industry dynamics.

For Research Question One (RQ1) findings suggest that operational costs, market demand, and the creditworthiness of charterers emerged as primary factors in chartering decisions. The strong emphasis on operational costs aligns closely with predictive model findings, where variables such as voyage turnaround times and net earnings were shown to significantly influence decision-making. The focus on charterer reputation and eco-friendly demand highlights a shift towards risk management and sustainability, aligning with regulatory pressures and the industry's gradual move towards environmentally conscious practices.

Research Question Two (RQ2) findings underscore fluctuating market conditions, regulatory compliance, and economic downturns as major barriers, reflecting the unstable environment that shipowners must navigate. These challenges emphasize the necessity for adaptive strategies to manage market volatility and regulatory complexities. Notably, the industry's sensitivity to geopolitical shifts underscores the importance of proactive, market-responsive approaches, a point validated by the model's focus on external variables impact on earnings and operational resilience.

In **Research Question Three (RQ3),** the sales-and-leaseback financial model is widely viewed as beneficial for enhancing liquidity, supporting capital reinvestment, and improving financial flexibility. The model's emphasis on predictable lease payments aligns with industry priorities for cash flow stability, corroborated by predictive models focusing on revenue management. However, varying perceptions around long-term planning implications suggest that while advantageous, the model requires tailored, strategic planning to fit specific organizational contexts.
The integration of predictive modeling with survey findings adds further dimension to these insights. By cross-referencing prioritized variables such as operational costs and market dynamics with industry feedback, this study reinforces the significance of data driven decision-making. The consistent themes of adaptability, resilience, and financial stability across the research questions reflect the industry's focus on sustainable growth in an evolving global context.

4.5 Conclusion

The findings of this study reveal a comprehensive understanding of the operational, financial, and strategic complexities within the tanker shipping industry. Key insights highlight that operational costs, market demand, and charterer reliability are essential drivers in chartering decisions, reflecting the industry's focus on financial stability and risk mitigation. These priorities are aligned with the industry's overarching need for adaptable strategies that balance immediate operational demands with long-term sustainability goals. The increasing emphasis on eco-friendly practices and technological advancements also underscores a proactive response to evolving regulatory landscapes and the push for sustainability in global markets, marking a shift towards responsible and forward-thinking business practices.

In analyzing the challenges faced by industry professionals, the study surfaces significant barriers such as market volatility, regulatory compliance, and economic fluctuations. These challenges emphasize the necessity for adaptive strategies capable of navigating external disruptions. Furthermore, insights into technological limitations and skill gaps suggest that targeted improvements in digital infrastructure and workforce capabilities could enhance operational efficiency, positioning companies to better handle the complexities of modern chartering practices. The interconnectedness of these barriers with broader market and geopolitical trends indicates a dynamic environment where resilience is key, reinforcing the need for industry players to adopt robust risk management frameworks and flexible operational models.

The sales-and-leaseback financial model emerges as a promising tool for enhancing liquidity, increasing financial flexibility, and supporting strategic growth within the industry. Its advantages, such as predictable lease payments and tax benefits, resonate with the industry's emphasis on cash flow stability and profitability.

However, the model's implications for long-term financial planning introduce a nuanced perspective, suggesting that while it provides immediate capital relief, careful consideration of organizational needs and risk tolerance is essential for sustained benefit.

This model exemplifies the industry's ongoing shift towards financial strategies that balance operational control with financial adaptability.

The integration of predictive modeling with these findings further validates the study’s insights. By aligning machine learning outputs on key metrics such as operational expenses and revenue potential with industry professionals perspectives, this study underscores the value of data driven decision-making in a volatile market. The consistency between predictive model priorities and survey results reinforces the importance of a data informed approach, supporting strategic planning in areas like chartering decisions, risk management, and financial stability. Together, these insights provide a robust foundation for industry stakeholders, offering actionable recommendations to enhance resilience, competitiveness, and adaptability in the face of both immediate and long term challenges.

In conclusion, the study highlights critical pathways for tanker shipping companies to navigate an increasingly complex global environment. By emphasizing sustainable practices, resilient financial models, and advanced technological solutions, industry professionals can proactively address regulatory, economic, and market pressures. This alignment between empirical findings and industry insights offers a practical roadmap for strategic innovation, positioning companies to thrive amid uncertainty. Future research may expand on these findings by examining the evolving impacts of digital transformation and financial strategies on operational efficiency and competitiveness, further supporting the industry's adaptability in an ever changing landscape.

CHAPTER V
DISCUSSION

This chapter provides a comprehensive analysis of the study's findings, primarily examining how predictive modeling and survey analysis contribute to operational, financial, and strategic decision-making in the tanker shipping industry.

The results from Chapter 4 underscore the critical factors driving chartering practices, including market demand, operational costs, and regulatory compliance, as well as the industry's perceptions of financial models like sales-and-leaseback. Building on the quantitative and qualitative methodologies outlined in Chapter 3, this discussion connects predictive model outputs with industry challenges to highlight how data driven solutions can optimize chartering and financial strategies.

While the focus remains on predictive models and their applications developed in Chapter 3, this discussion also considers the potential of Natural Language Processing (NLP) enhancements, specifically a Retrieval-Augmented Generation (RAG) model, as a supplementary tool for improving user accessibility and decision-making efficiency. This NLP based framework, although not central to the analysis, is explored as a future add on that could help make the predictive insights from Chapter 3 more intuitive, interactive, and accessible to end users, particularly those with limited technical expertise.

The analysis is structured around each research question, incorporating key findings from Chapters 3 and 4 to explore how predictive modeling addresses industry challenges and proposing that an NLP driven system could further enhance decision-making by simplifying data interpretation.

5.1 Discussion of Results

The findings of this study emphasize the transformative potential of AI/ML based predictive modeling and survey analysis in the tanker shipping industry, particularly for decision-making processes that impact operations, finance, and strategy. This section explores how the combined use of predictive models and industry survey insights offers actionable pathways for addressing the pressing challenges faced by tanker operators, including market volatility, regulatory pressures, and environmental demands.

By analyzing the results considering each research question, this section delves into the operational and strategic implications of the study's findings and considers the theoretical addition of an NLP based Retrieval-Augmented Generation (RAG) model to further enhance data accessibility.

According to (Ghosh, 2024) Retrieval-Augmented Generation refers to an advanced natural language processing technique that combines the strengths of both retrieval models and generative models.

Predictive Modeling: An Asset in Navigating Operational Complexities

The use of predictive models in this study, including XGBoost and linear regression, provided a robust framework for understanding and optimizing voyage fixture decisions. Predictive modeling contributed quantitative insights into key metrics such as voyage turnaround times, net earnings, and fuel efficiency. These insights revealed several critical points relevant to daily operational decisions:

1. Operational Costs and Fuel Consumption:

The models revealed that operational costs, particularly fuel consumption, are central to the profitability of each voyage. By predicting fluctuations in fuel costs based on route distance, sailing days, and port congestion, the model allows for more precise cost management. In real-world applications, this predictive capability could help operators optimize routes based on fuel efficiency, minimizing unnecessary expenses and enhancing profitability. This is especially important in a volatile fuel market, where even minor adjustments in fuel consumption could result in substantial savings over time.

2. Turnaround Time and Charter Earnings:

Predictive modeling effectively estimated turnaround times, a critical metric influencing net earnings and operational efficiency. In scenarios where port congestion or geopolitical factors delay voyages, the ability to forecast turnaround times allows for more informed route planning and voyage scheduling. By optimizing for shorter turnaround times, operators can potentially increase voyage frequency, enhancing revenue opportunities. Additionally, by associating faster turnaround times with higher charter earnings, the model highlights how efficiency directly impacts financial outcomes.

3. Enhanced Forecasting Capabilities for Market Volatility:

By employing XGBoost, the model could accommodate non-linear relationships, making it particularly useful for forecasting under volatile market conditions. This predictive capability aligns well with industry needs for dynamic pricing and cost management strategies. In practical terms, operators can use these forecasts to proactively adjust charter rates in response to market shifts, thereby maintaining competitive pricing and optimizing profit margins. This is especially pertinent in the current global economy, where fuel costs and freight rates are subject to frequent and sometimes drastic fluctuations.

NLP-Driven Theoretical Framework for Improved Decision-Making

In addition to predictive analytics, the theoretical introduction of an NLP-based RAG model offers a vision of how complex data insights could be made more accessible. This NLP-driven system would allow stakeholders to interact with predictive insights through natural language queries, removing the barrier of technical expertise.

1. Interactive and Contextual Insights for Non-Technical Stakeholders:

An NLP-driven model would allow users to ask straightforward questions like "What is the most cost-effective route given current fuel prices?" or "Which route minimizes turnaround time and maximizes earnings?" This model would retrieve relevant data, process it through an LLM, and provide answers that combine real-time market data with predictive insights. For non-technical stakeholders, this tool would make advanced analytics more accessible and intuitive, empowering a broader range of decision-makers within the organization to leverage data-driven insights.

2. Adaptation to Real-Time Conditions:

By integrating live data streams (e.g., weather conditions, fuel prices), the NLP model could offer recommendations tailored to real-time conditions, a feature particularly valuable in the unpredictable and fluctuating maritime environment.

For example, an operator seeking the best route during a sudden fuel price spike could ask the system for recommendations that prioritize fuel efficiency while balancing earnings potential. This interactive feature enhances adaptability, allowing operators to make agile adjustments in response to immediate market and environmental changes.

3. Improved Communication and Collaboration Across Departments:

An NLP-enhanced RAG model could facilitate smoother communication between departments by providing user-friendly data interpretations. Operations, finance, and management teams could each interact with the same dataset through questions tailored to their specific needs, promoting a unified understanding of strategic objectives. For example, operations might focus on route optimization, while finance could prioritize profitability, and both teams would receive customized yet aligned insights from the same data sources.

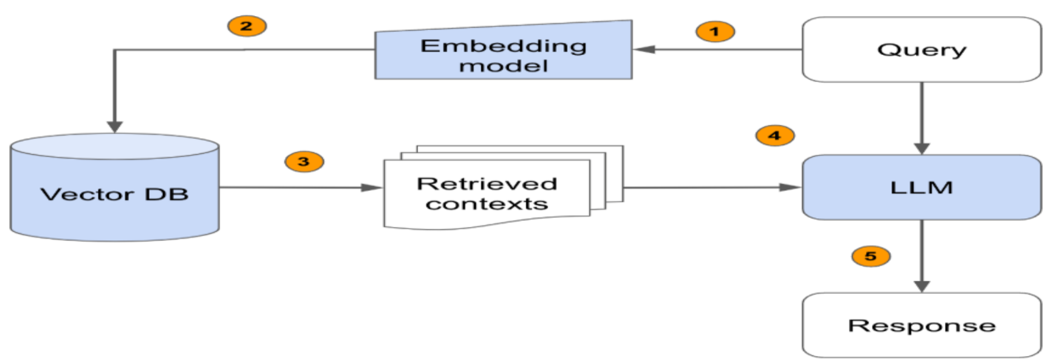


Figure 15. Illustrative diagram of NLP data retrieval and processing workflow (Ghosh, 2024)

This diagram would provide a high-level visualization of the RAG model, illustrating how data retrieval, LLM processing, and user interface work together to produce context-aware recommendations. This theoretical framework lays a foundation for future development, potentially transforming the tanker shipping industry's approach to data and decision making.

5.2 Discussion of Research Question One

RQ1: How do ship owners fix their ships on charters at present day?

Analysis of Key Influencing Factors

The analysis of RQ1 underscored the importance of operational costs, market demand, and the reliability of charterers in making effective chartering decisions. Predictive modeling provided quantitative insights, reinforcing the prioritization of these factors and offering actionable strategies for optimizing chartering practices in the tanker shipping industry.

1. Importance of Operational Cost Management

Operational costs emerged as the primary driver in chartering decisions, as highlighted by both predictive modeling and survey responses. Predictive models analyzed variables such as fuel prices, crew wages, port fees, and maintenance costs, revealing their significant impact on voyage profitability. For instance, even minor fluctuations in fuel prices can drastically affect a ship's overall cost efficiency, especially for long haul routes where fuel comprises a major portion of expenses.

Predictive Models in Cost Forecasting: By leveraging predictive models to forecast cost components, operators can refine budget planning and allocate resources more efficiently. The ability to anticipate changes in bunker fuel prices or predict port fees enables operators to optimize their chartering decisions by selecting routes and partners that best balance costs and profitability. Predictive models allow for scenario analysis, where operators can explore multiple cost variables and assess their impact on overall voyage returns.

Enhanced Budget Control and Resource Allocation: The insights from predictive models help operators identify cost-saving opportunities, such as selecting routes with lower port fees or optimizing fuel consumption patterns.

By aligning predictive cost forecasts with real-time data, operators can better manage budget constraints, enhancing profitability and ensuring more stable financial performance over multiple voyages. For instance, a model driven approach to bunker cost forecasting can allow operators to plan fuel efficient routes proactively, leading to substantial long-term savings.

2. Reliability and Reputation of Charterers

The survey results emphasized the importance of charterer reliability and reputation, highlighting a preference for trustworthy and financially stable partners. In a high-stakes industry like tanker shipping, where payment defaults or contract disputes can lead to significant financial losses, the choice of charterer is a critical risk factor. Reliable partnerships with charterers who have a strong track record of timely payments and ethical practices minimize contractual risks and contribute to operational stability.

Risk Assessment Through Data Backed Charterer Selection: An NLP driven system could offer a valuable tool for assessing the reputation and creditworthiness of potential charterers. By enabling users to query the charterer's history, payment behavior, and prior contractual performance, the system could generate comprehensive risk profiles for each potential partner. For example, if a charterer has a history of late payments or defaulting on agreements, the NLP system could flag this as a potential risk, allowing operators to make informed decisions.

Reducing Contractual and Payment Risks: Integrating predictive insights with an NLP interface that presents easy to access risk assessments would allow ship operators to make data driven decisions about partnerships. This proactive approach to risk mitigation aligns with the industry’s objective of reducing exposure to financial and operational disruptions. Reliable partnerships help ensure timely revenue generation and smooth contract fulfillment, enhancing the stability of tanker operations.

3. Sustainability and Eco-Friendly Practices

The growing emphasis on sustainability within the industry was also evident in the survey responses, with many stakeholders indicating the increasing importance of eco-friendly practices in chartering decisions. As regulatory bodies and environmental organizations exert pressure to reduce emissions, the demand for sustainable operations has become both a regulatory requirement and a competitive differentiator.

Incorporating Emissions Data into Predictive Models: Predictive models that account for emissions and environmental impact metrics could assist operators in selecting routes and chartering options that align with sustainability goals. By integrating emissions data, these models could provide insights on fuel efficiency, route optimization, and compliance with environmental regulations, supporting operators in achieving greener operations. For example, a model that identifies the most fuel-efficient route can help reduce carbon emissions, meeting regulatory standards while enhancing cost efficiency.

NLP-Driven Environmental Querying: An NLP-based system could further enhance decision-making by allowing operators to query environmental metrics for various routes and charter options. For instance, operators could ask, "What is the emissions profile of Route A compared to Route B?". This user-friendly interface would provide instant insights, helping operators align their route selection and chartering practices with sustainability targets and regulatory requirements. This accessibility makes it easier for operators to prioritize eco-friendly practices without requiring in-depth technical knowledge, supporting broader adoption of sustainable operations across the industry.

Aligning with Industry-Wide Environmental Goals: By integrating sustainability metrics into predictive modeling and making them accessible through NLP, the industry can align its operational practices with global sustainability initiatives. This not only helps tanker operators meet regulatory standards but also enhances their reputation as environmentally responsible businesses. Charterers increasingly value eco-friendly practices, which could lead to more favorable contracts and long-term partnerships, giving operators a competitive edge in a market that is progressively prioritizing sustainability.

4**. Strategic Use of Predictive Insights for Market Demand**

Understanding and responding to market demand is crucial for optimizing chartering decisions, as market fluctuations significantly impact the viability of charter rates, route profitability, and operational timing. Predictive models enable stakeholders to forecast demand trends and identify routes with the highest revenue potential, thereby maximizing voyage profitability.

Adapting to Demand Cycles and Market Trends: By forecasting demand cycles, predictive models help operators adapt their chartering strategies to market trends, allowing them to select routes with high charter rates or high demand for specific cargo types. These insights provide operators with a competitive advantage by ensuring that they are not only filling capacity but doing so with routes and cargo that yield the highest returns. For instance, if the model predicts an upcoming increase in demand for routes serving specific ports, operators can proactively position their ships to capitalize on this trend.

Dynamic Route Selection for Maximum Profitability: Predictive insights enable more dynamic route selection, where operators can adjust their routes based on anticipated demand fluctuations. This flexibility allows operators to maximize revenue by selecting routes that align with short-term demand peaks or adjusting schedules to avoid low-demand periods. The ability to pivot chartering strategies in response to demand data enhances both revenue generation and resource utilization.

NLP Queries for Market Demand Insights: An NLP-driven system could enhance decision-making by providing real-time responses to demand-related queries. For example, an operator could ask, “What are the projected demand trends for Route X over the next quarter?". The system would deliver insights based on historical data and current market analysis, helping operators make informed decisions. This feature ensures that operators are equipped with the latest market intelligence, making it easier to align chartering strategies with evolving market conditions.

Summary of RQ1 Discussion

The analysis of RQ1 demonstrates how predictive modeling significantly enhances chartering decisions in the tanker shipping industry by prioritizing key factors such as operational costs, charterer reliability, sustainability, and market demand. Predictive models enable stakeholders to forecast critical costs like fuel prices and port fees, assess the reliability of charterers, and make environmentally conscious route selections, ultimately supporting profitable and sustainable operations.

Additionally, while not central to the current analysis, an NLP driven system could supplement these predictive insights by providing an intuitive way for operators to access complex data. With NLP, stakeholders could easily query information on charterer reliability, cost efficiency, and eco-friendly options, receiving tailored responses that streamline decision making processes. This added layer of accessibility could further bridge the gap between data driven insights and practical application, making predictive analytics more user-friendly and actionable.

Together, predictive modeling and NLP-driven accessibility form a comprehensive approach, helping the tanker shipping industry move from experience-based decision-making to a data-informed strategy. This shift not only supports efficient resource allocation and risk management but also prepares industry stakeholders to adapt to market fluctuations, regulatory changes, and sustainability demands with greater agility and resilience.

5.3 Discussion of Research Question Two

RQ2: What are the associated problems they face and the barriers?

Examination of Industry Barriers and Adaptive Strategies

The analysis of RQ2 sheds light on significant challenges within the tanker shipping industry, particularly focusing on the barriers to optimal decision making. Core obstacles include market volatility, stringent regulatory requirements, and limitations in technology and skills. Each of these barriers impacts the industry's ability to operate efficiently and competitively. Predictive modeling and NLP driven tools can provide targeted solutions to mitigate these issues, fostering resilience and adaptability across the sector.

Navigating Market Volatility Through Predictive Insights: Market volatility is one of the primary challenges identified in the analysis, particularly in fluctuating freight rates and fuel costs. The tanker shipping industry is highly sensitive to these economic fluctuations, which can drastically impact profit margins and make forecasting challenging. Predictive models, however, can offer a structured approach to managing this volatility by analyzing historical and real-time data to project trends and identify high profit routes or cost-effective operational adjustments. For instance, by forecasting potential cost impacts from volatile fuel prices, predictive models can guide route selection that minimizes costs while maximizing returns.

In addition, an NLP driven Retrieval-Augmented Generation (RAG) system could enhance this process by delivering real-time market insights in response to user queries, such as "Which routes are currently most profitable given recent fuel price hikes?".

By dynamically analyzing market conditions and comparing profitability across routes, this system could provide users with adaptive strategies based on the latest data. This combined approach allows stakeholders to make data-backed adjustments in response to economic changes, thereby reducing risks and ensuring more stable operations.

<u>Addressing Regulatory Compliance Challenges</u>: Regulatory compliance is another substantial barrier, especially given the increasing number of environmental and safety regulations imposed on the industry. Compliance with emission standards, waste management protocols, and safety regulations requires not only significant financial resources but also constant monitoring and adaptation. The predictive modeling framework provides a quantitative perspective by estimating the cost implications of these compliance requirements, enabling operators to budget for regulatory expenses more accurately.

An NLP based system could further assist by automating regulatory updates and compliance checks. For example, a user query such as "What are the latest emission regulations for tankers operating in European waters?" could prompt the system to retrieve and synthesize the latest regulatory data, presenting users with concise and actionable insights. This feature would help ship operators stay informed and compliant, thereby reducing the risk of penalties and enhancing operational efficiency. By providing on-demand access to regulatory information, NLP tools facilitate proactive compliance management, allowing companies to adjust their operations as needed to align with evolving regulatory standards.

<u>Overcoming Skill Gaps and Technology Limitations</u>: Skill gaps and limited technological expertise emerged as significant barriers, particularly in implementing and interpreting advanced predictive models.

As the industry moves towards data-driven practices, the shortage of technical skills among decision-makers can inhibit the effective use of predictive analytics. Predictive models can provide in-depth insights, but without accessible interfaces and interpretation aids, these insights may remain underutilized.

NLP-driven systems offer a solution by democratizing access to complex data, making insights more interpretable for non-technical users. For instance, an NLP interface could enable a ship manager to ask, "What operational adjustments can I make to lower fuel costs on my current routes?". The system could then retrieve relevant predictive insights, translating complex model outputs into clear, actionable recommendations.

This ease of access to data insights enables a broader range of stakeholders to engage with data-driven practices, supporting better decision-making across all levels of the organization. By bridging the gap between advanced analytics and practical applications, NLP systems empower industry professionals to leverage predictive modeling without requiring specialized technical expertise.

Adapting to Geopolitical Uncertainty and Economic Downturns: Geopolitical factors, such as trade restrictions, tariffs, and international disputes, contribute significantly to the volatility of the tanker shipping market. Economic downturns also pose a challenge, impacting charter demand and profitability. Predictive models can help mitigate the effects of these factors by analyzing economic and geopolitical trends, thereby forecasting demand and highlighting potential operational risks. For example, a predictive model could identify regions where tariffs or trade restrictions are likely to affect cargo flow, enabling operators to redirect resources or adjust chartering strategies accordingly.

By coupling these predictive insights with NLP driven tools, stakeholders can query the system about potential risks and mitigation strategies. For instance, they might ask, "How will the latest geopolitical developments impact my route profitability?".

The NLP system could provide a synthesized response, incorporating both predictive data and real-time geopolitical information. This interactive capability allows ship managers to remain agile and adapt operations to mitigate risks associated with external factors, ensuring continuity even in volatile market conditions.

Promoting Eco-Friendly Practices and Sustainability: Sustainability is a growing focus within the tanker shipping industry, especially as regulatory pressures increase. Adopting eco-friendly practices can contribute to regulatory compliance, improve public perception, and support long term operational sustainability. Predictive models can play a vital role by analyzing emission levels, fuel efficiency, and cost implications, allowing operators to select routes that optimize both profitability and environmental impact.

In addition, an NLP system could allow operators to query environmental metrics directly, making it easier to align operational strategies with sustainability goals. For example, by asking “Which route has the lowest environmental impact based on current conditions?” stakeholders can receive data-driven recommendations that prioritize eco-friendly practices. This capability not only aids compliance but also positions companies favorably within an increasingly eco-conscious market, enhancing their reputation and competitive edge.

Summary of RQ2 Discussion

The discussion of RQ2 highlights how predictive modeling and NLP driven tools can collectively address major barriers in the tanker shipping industry, including market volatility, regulatory compliance, skill gaps, and sustainability challenges. Predictive models provide quantitative insights into economic fluctuations, regulatory costs, and environmental impact, supporting proactive strategies that improve resilience and adaptability. NLP-driven systems enhance these capabilities by simplifying access to complex data, enabling stakeholders to make informed decisions through user friendly, query-based interactions.

By integrating predictive analytics with NLP accessibility, stakeholders can transition from a traditional, experience related decision-making approach to a more adaptive, data driven approach. This shift allows the tanker shipping industry to navigate regulatory pressures, geopolitical uncertainties, and economic fluctuations more effectively, establishing a foundation for sustainable and competitive operations. As the industry continues to embrace data driven practices, it is better positioned to align operational strategies with long term goals, ensuring resilience and agility in a dynamic global landscape.

5.4 Discussion of Research Question Three

RQ3: How can the Sales-and-leaseback financial model be applied by ship owners and managers efficiently in the maritime industry to become competitive and generate more profits?

Financial Strategies: Sales-and-Leaseback Model

The sales-and-leaseback financial model offers significant advantages for tanker shipping companies by providing liquidity, stabilizing cash flow, and maintaining operational flexibility.

This approach allows ship owners to access capital without sacrificing control of assets, making it a valuable tool in an industry characterized by high capital demands and fluctuating market conditions. The analysis in this section explores how predictive modeling and NLP driven tools can enhance decision making around sales-and-leaseback, offering insights into cash flow stability, risk management, operational flexibility, and tax benefits.

Enhancing Liquidity and Financial Flexibility: Liquidity is crucial in the capital-intensive tanker shipping industry, where timely access to funds can support investments in fleet expansion, technology upgrades, and regulatory compliance. The sales-and-leaseback model enhances liquidity by enabling ship owners to sell assets and lease them back, thereby freeing up capital for reinvestment. Predictive models can assist in determining the optimal timing and structure for leaseback transactions by forecasting cash flows and evaluating the economic impact of these arrangements over time.

An NLP-driven tool can complement this by allowing stakeholders to query specific financial outcomes, such as, "How will sales-and-leaseback affect cash flow under different market conditions?".

The system could retrieve relevant financial data, providing a comprehensive overview that enables ship owners to make well-informed, scenario-based decisions about liquidity needs. By bridging real-time data and predictive insights, this approach supports proactive financial planning and strategic reinvestment.

Supporting Cash Flow Stability for Long-Term Planning: Predictable lease payments from sales-and-leaseback arrangements offer tanker operators a stable revenue stream, which is particularly valuable during periods of economic volatility or market downturns. This cash flow stability aids in planning and budgeting, reducing the company's dependency on fluctuating freight rates. Predictive models can quantify these cash flow benefits by projecting lease payments against operational expenses and market conditions. An NLP-based tool could further enhance this by providing tailored insights in response to user queries like, "What are the expected cash flow benefits of sales-and-leaseback over the next five years?". By analyzing financial patterns and modeling future scenarios, 4this tool enables decision makers to assess the model's long-term benefits for cash flow management, ensuring sustainable planning and financial security. Such functionality aligns with industry needs for stable, predictable revenue streams that allow companies to navigate uncertain market conditions confidently.

Risk Management through Financial Predictability: The sales-and-leaseback model also serves as a risk mitigation strategy by transferring asset ownership while maintaining operational control. This balance allows companies to reduce exposure to risks related to asset depreciation and market fluctuations, while still benefiting from steady revenue through lease payments. Predictive models can evaluate risk factors by simulating different market scenarios, such as fuel price hikes or drops in freight rates, helping stakeholders understand how these events could impact leaseback profitability.

To complement this analysis, an NLP driven tool could allow users to explore potential risk scenarios by querying, "What are the risks associated with sales-and-leaseback in volatile markets?".

By retrieving and analyzing historical data on market fluctuations, the system could highlight potential vulnerabilities and offer insights into best practices for managing risk within the leaseback model. This approach helps companies identify and address potential financial challenges proactively, reinforcing the model's role as a strategic risk management tool.

Maintaining Operational Control with Financial Advantages: One of the primary advantages of the sales-and-leaseback model is that it allows companies to maintain operational control over their assets while benefiting from capital flexibility. This flexibility is essential in an industry that requires rapid responses to shifting market demands. Predictive modeling can help evaluate how operational decisions, such as route selection or fleet utilization, align with financial objectives under a leaseback arrangement, supporting decisions that maximize both operational and financial outcomes.

An NLP driven interface could enhance accessibility to these insights by enabling users to ask questions like, "How does sales-and-leaseback impact operational flexibility?". This tool could aggregate data on operational performance, lease terms, and projected returns, providing an overview of how the model supports decision-making in real-world operational contexts. This functionality emphasizes the importance of maintaining operational autonomy while leveraging financial benefits, ensuring that tanker operators remain agile and responsive to market dynamics.

Optimizing Tax Benefits and Financial Performance: The sales-and-leaseback model can provide tax advantages through deductions on lease payments, contributing to overall profitability. However, understanding and maximizing these benefits requires careful analysis of tax regulations, which vary across regions. Predictive models can assist by estimating tax savings under different scenarios, incorporating these savings into cash flow and profitability projections to provide a complete view of the financial implications.

An NLP driven tool could further support this by enabling stakeholders to query tax-related outcomes, such as "What are the tax benefits of sales-and-leaseback in specific regions?". By pulling data on regional tax laws and analyzing the financial implications, the system allows ship owners to explore potential savings and adjust their strategies to benefit from tax relief effectively. This feature provides an accessible way to navigate complex tax regulations, ensuring that the full financial advantages of the sales-and-leaseback model are realized.

Summary of RQ3 Discussion

The analysis of RQ3 emphasizes how predictive modeling and NLP-driven tools can jointly support the effective implementation of the sales-and-leaseback model in tanker shipping, enhancing liquidity, cash flow stability, risk management, and operational flexibility. By providing actionable insights into key financial factors, these tools empower stakeholders to make informed decisions that align with long-term strategic goals.

Predictive models offer valuable projections on cash flow, tax savings, and risk factors, helping ship owners assess the financial viability of sales-and-leaseback under various economic scenarios. Meanwhile, NLP-driven tools enhance accessibility by allowing stakeholders to explore these insights through intuitive queries, receiving context-specific answers that support decision-making in real-time. Together, these tools enable tanker operators to navigate financial complexities with greater confidence, ensuring resilience, profitability, and competitiveness in an evolving maritime industry.

The combined use of predictive analytics and NLP interfaces represents a shift toward a more data-driven approach to financial management, equipping the tanker shipping industry with robust strategies for sustainable growth and financial security. By embracing these tools, industry stakeholders can optimize financial strategies in alignment with operational objectives, ensuring both stability and adaptability in a dynamic market.

Final Summary

The findings across all research questions indicate that predictive modeling and NLP frameworks offer transformative potential for the tanker shipping industry, equipping stakeholders with data-driven strategies for chartering, managing regulatory pressures, addressing market volatility, and enhancing financial resilience through sales-and-leaseback. Predictive analytics allow for accurate forecasting and informed decision-making, while NLP driven interfaces make these insights accessible, bridging the gap between complex data and practical application.

The combined application of predictive models and NLP systems promotes a data-informed approach, supporting tanker shipping operators in adapting to regulatory and market shifts, sustainability demands, and financial challenges. This approach aligns with the industry's goals for agility, resilience, and competitive advantage, fostering sustainable growth and strategic stability in a dynamic global environment.

CHAPTER VI

SUMMARY, IMPLICATIONS, AND RECOMMENDATIONS

6.1 Summary

This study explores the transformative role of Artificial Intelligence (AI), Machine Learning (ML), and data driven strategies in the tanker shipping industry, focusing on predictive analytics, financial modeling, and the potential of Natural Language Processing (NLP) systems to support industry decision making. The research addresses the operational, financial, and strategic challenges faced by stakeholders in a volatile and competitive market, proposing an innovative AI based framework that combines quantitative insights from predictive models with qualitative perspectives from industry surveys. Additionally, this study examines the applicability of the sales-and-leaseback financial model, positioning it as a viable strategy to enhance liquidity and risk management within the sector. The findings underscore the value of data driven decision-making and collaborative strategies to enable resilience, efficiency, and sustainability in the maritime industry.

Recap of Each Chapter

Chapter 1 (Introduction): This chapter introduces the study's context, focusing on the unique challenges in tanker shipping, including market volatility, regulatory compliance, and financial constraints. It defines the research questions that guide the analysis: understanding chartering practices, identifying operational barriers, and exploring the potential of financial models like sales-and-leaseback in enhancing competitiveness.

Chapter 2 (Literature Review): This chapter provides an extensive review of existing literature on AI/ML applications, maritime finance, and operational challenges in the shipping industry. The literature review highlights gaps in applying AI to optimize tanker operations and financial decisions, establishing the relevance and potential impact of this research within the field.

Chapter 3 (Methodology): This chapter outlines the research design and data analysis techniques. It explains the study's quantitative and qualitative approaches, including predictive modeling methods (e.g., XGBoost and linear regression) to forecast key metrics like turnaround times and earnings, and survey analysis to capture industry perspectives on operational barriers and financial strategies. This chapter provides a solid, evidential based foundation for the research findings.

Chapter 4 (Results): This chapter presents the results of the predictive modeling and survey data analysis. Findings indicate that market demand, operational costs, and charterer reputation are significant factors in chartering decisions, while market volatility and regulatory compliance are prominent barriers. The sales-and-leaseback model is identified as a tool for enhancing liquidity and managing financial risk, with mixed responses regarding its usefulness in the long run.

Chapter 5 (Discussion): This chapter synthesizes the findings, discussing the implications of predictive modeling in managing industry challenges. It introduces the theoretical concept of NLP driven solutions, such as Retrieval-Augmented Generation (RAG) systems, which could provide non-technical users with seamless access to AI-generated insights. This chapter emphasizes technology's role in overcoming operational barriers.

Key Findings and Contributions

Operational Insights: Predictive modeling provides data driven insights into operational decisions, highlighting the importance of variables such as route distance, fuel costs, and charterer reputation in determining voyage profitability and efficiency. These insights enable proactive planning and align with the industry's need for agile responses to market changes.

Financial Resilience: The survey analysis reveals that stakeholders view the sales-and-leaseback model as a viable strategy to improve liquidity and financial flexibility. However, successful implementation requires careful planning, particularly in terms of long run financial impacts, cash flow management, and operational control.

NLP-driven Accessibility: Although theoretical in this study, NLP tools, such as RAG systems, offer a vision for enhancing user accessibility to complex data, making AI insights available to non-technical stakeholders. This concept highlights future opportunities for democratizing data driven decision-making within the industry.

6.2 Implications

The findings of this study carry broad implications for the tanker shipping industry, providing valuable insights into how predictive modeling, financial strategies, and NLP-driven accessibility can be leveraged to address market volatility, regulatory compliance, financial resilience, and sustainability. Each implication is explored below, focusing on practical and strategic adaptations that can drive the industry forward in a highly dynamic environment.

Navigating Market Volatility with Predictive Analytics

Proactive Decision-Making: One of the primary advantages of predictive analytics is the ability to anticipate market changes and adjust operations accordingly. By forecasting variables such as fuel prices, charter rates, and operational costs, stakeholders can proactively adapt to fluctuations rather than reacting after the fact. Predictive models provide chartering managers with data on high demand routes, expected seasonal shifts, and optimal timings for voyages, enabling them to plan routes that maximize profitability and minimize exposure to adverse market conditions.

Enhanced Cost Control: Predictive analytics helps operators identify cost-saving opportunities, such as fuel-efficient routes and cost-effective maintenance schedules, which are particularly useful in a volatile market. For example, predictive insights on expected fuel price fluctuations allow companies to strategically plan bunker purchases or adjust routes, mitigating the financial impact of price hikes. This capability aligns with the industry's objective to optimize profitability and resource allocation while managing cost volatility.

Improved Voyage Planning: Predictive analytics aids in accurate voyage planning by projecting turnaround times, port availability, and demand levels. In volatile markets, this enables stakeholders to strategically position vessels, anticipate route demand, and optimize fleet utilization.

This shift from experience based to data driven voyage planning represents a critical advancement in managing the industry's inherent unpredictability.

Enhanced Compliance with Regulatory Requirements

Real-Time Compliance Monitoring: Regulatory requirements, especially those relating to emissions and environmental protection, demand strict adherence, with non-compliance potentially leading to penalties, delays, or reputational damage. AI-driven compliance tools can automate the monitoring of vessel emissions, fuel consumption, and adherence to international standards, reducing administrative overhead and ensuring continuous compliance with evolving regulations.

Industry Collaboration on Compliance: Establishing collaborative compliance platforms within the industry could simplify regulatory adherence and reduce redundancies across organizations. These shared platforms could consolidate updates on regulatory changes, best practices, and compliance requirements, offering stakeholders a centralized source for ensuring adherence to international standards. Collaboration in compliance not only reduces risks for individual companies but also fosters a united approach to industry-wide issues like sustainability and environmental responsibility.

Optimizing Financial Strategies through Sales-and-Leaseback Models

Liquidity Enhancement and Cash Flow Stability: The sales-and-leaseback model provides shipowners with a method to free up capital while retaining operational control over their vessels, creating an attractive option for companies seeking liquidity without sacrificing asset control. This study identifies the importance of structured guidance in implementing this model, as educational resources could help stakeholders understand the cost benefit analysis, cash flow management, and long run implications of leaseback arrangements.

Industry Training for Strategic Implementation: Introducing educational programs, workshops, and online resources focused on sales-and-leaseback models can provide stakeholders with comprehensive insights into this financial tool.

Such resources would address essential topics, including tax implications, risk management, and operational control, enabling companies to adopt the model confidently. Additionally, industry associations could provide structured forums and peer learning platforms for exchanging experiences and best practices in sales-and-leaseback arrangements. There might be maritime forums

Facilitating User-Friendly Access to Data through NLP Enhancements

Natural Language Processing (NLP) for Non-Technical Users: With NLP-driven systems, such as Retrieval-Augmented Generation (RAG) models, industry stakeholders can access predictive insights and data analysis through conversational language, bypassing the need for technical expertise. This technology enables users to query complex data on demand, making insights accessible to stakeholders across departments ranging from finance to operations thereby supporting a data-driven culture within organizations.

Real-Time Decision-Making Support: By integrating NLP-driven models with real-time data sources, such as market forecasts, weather updates, and port availability, the industry could enable users to make informed decisions on-demand. This approach democratizes access to data-driven insights, allowing various organizational roles to contribute to data-informed decision-making. Ultimately, NLP provides a way for stakeholders to engage with data without deep technical knowledge, creating a user-centric approach to leveraging AI insights.

Promoting Sustainable Practices and Environmental Responsibility

Emissions Optimization: Predictive models that incorporate data on fuel consumption and emissions can guide route and operational planning to minimize environmental impact. Operators can use these insights to select eco-friendly routes, adopt energy-efficient operational practices, and ensure compliance with emissions regulations. By prioritizing eco-friendly operations, companies align with global regulatory standards and bolster their reputation as responsible industry participants.

Investment in Green Technologies: As sustainability increasingly becomes a market differentiator, investing in green technologies, such as low-emission engines and energy-efficient systems, supports long-term resilience and compliance. Predictive analytics can further enhance these efforts by identifying operational adjustments that improve fuel efficiency and reduce emissions, offering a measurable approach to sustainability goals. Proactive environmental practices not only benefit the company's public image but also contribute to meeting international sustainability commitments.

Leveraging Advanced Technology to Build Industry Resilience

Data-Driven Resilience Frameworks: The integration of AI, ML, and predictive modeling creates a resilient operational framework for the maritime industry, allowing companies to quickly adapt to market fluctuations, regulatory shifts, and financial pressures. A data-driven approach offers a competitive edge by supporting rapid, evidence-based decisions that optimize both short-term efficiency and long-term strategic stability.

Collaborative Resilience Initiatives: Building shared resilience through collaborative platforms and data-sharing initiatives within the industry offers a means for smaller companies to access advanced technology and data resources. Industry-wide data sharing, particularly around compliance and predictive insights, ensures that all participants are equipped with tools to respond to market pressures, thereby fostering a more resilient and unified industry ecosystem.

6.3 Recommendations for Future Research

To further support the tanker shipping industry's transition to a data driven, resilient, and sustainable operation, future research can build upon the findings of this study by exploring advanced modeling techniques, real-time data integration, expanded NLP applications, and collaborative frameworks. The following recommendations outline priority areas for future investigation, each with potential to enhance the capabilities and impact of AI driven strategies within the sector.

Expanding Predictive Modeling Techniques

Deep Learning Models: Research into advanced machine learning models, particularly deep learning techniques like Recurrent Neural Networks (RNNs) and Convolutional Neural Networks (CNNs), could provide more nuanced predictions by capturing temporal and spatial data relationships. RNNs can address sequential dependencies, making them suitable for time-series data such as route turnaround and earnings forecasts, while CNNs could be adapted for spatial analysis in route optimization and environmental impact forecasting.

Comparative Model Performance Analysis: Comparing the performance of various algorithms, including support vector machines, decision trees, and ensemble methods, could reveal the optimal approach for different predictive tasks within the maritime sector. For example, analyzing the relative effectiveness of linear regression versus decision trees in predicting fuel costs or charter earnings could provide actionable insights for stakeholders.

Real-Time Data Integration for Dynamic Decision-Making

Development of Data Pipelines: Future research should focus on developing data pipelines capable of integrating real time data, including fuel prices, weather forecasts, and port conditions. This capability would enable predictive models to provide continuously updated insights, allowing for responsive adjustments in operations and cost management.

Real time data integration is particularly relevant for dynamic decision-making in volatile market conditions.

Collaborative Partnerships for Real-Time Data Access: Collaborating with data providers and technology companies to secure API access to relevant real-time data sources, such as environmental forecasts, geopolitical developments, and global market indexes, would enhance predictive models' relevance and accuracy in live settings.

Enhanced Application of Natural Language Processing (NLP) Tools

Implementation of Retrieval-Augmented Generation (RAG) Models: Prototyping RAG models designed for industry specific queries (custom models) could enable stakeholders to interact with data systems through plain language, enhancing data accessibility for non-technical users. For example, users could ask questions like, "What's the projected demand for Route X?" and receive data-driven insights without needing analytical expertise.

User-Centric NLP Tools: Testing NLP models usability and effectiveness in various operational settings would ensure they can accommodate industry complexities and stakeholder needs. Future research should examine how NLP can support user driven inquiries related to operational planning, compliance, and financial strategies, particularly in enabling cross-departmental collaboration within organizations.

Assessing Sales-and-Leaseback Models in Different Market Conditions

Economic Contextualization of Financial Models: Exploring how the sales-and-leaseback model performs across various economic cycles would provide a nuanced understanding of its benefits and limitations. For example, analyzing its impact on cash flow during both downturns and growth periods could inform stakeholders about when this model is most effective.

Case Studies and Best Practices: Conducting case studies on companies that have successfully implemented sales-and-leaseback agreements under different market conditions could yield best practices, illustrating how to maximize benefits and minimize risks. This research could inform financial planning across the industry, offering insights on structuring lease agreements and assessing potential tax benefits.

Exploring AI and IoT Integration for Real-Time Monitoring

IoT Sensor Data Integration: Integrating IoT sensors on vessels could enable real-time monitoring of operational metrics, such as fuel levels, environmental conditions, and engine performance. This data could be incorporated into predictive models, allowing for immediate adjustments that enhance route efficiency, safety, and maintenance scheduling.

Cost-Effectiveness and Impact Analysis: Future research should assess the cost-effectiveness and operational impact of IoT in the maritime sector, focusing on its ability to improve compliance, sustainability, and efficiency. This analysis would provide a basis for evaluating IoT investments, particularly for smaller companies seeking affordable technology solutions.

Investigating Collaborative Industry Platforms

Shared Compliance and Data Platforms: Exploring the feasibility and structure of industry-wide data-sharing platforms could provide maritime stakeholders with affordable access to advanced technologies. Collaborative platforms for compliance monitoring, route optimization, and predictive modeling would benefit smaller companies, creating a more inclusive industry ecosystem.

Data Governance and Privacy Standards: Research into data governance frameworks for shared platforms would ensure that data-sharing agreements meet confidentiality, privacy, and regulatory standards.

Examining successful collaborative models in other industries, such as finance or logistics, could reveal best practices for implementing these platforms in the maritime sector.

Impact of Regulatory Changes on Predictive Models

Longitudinal Regulatory Impact Studies: Future research should examine the adaptability of predictive models as new regulations emerge, assessing the performance and accuracy of these models in the face of regulatory shifts. This research would identify areas for recalibration, ensuring that models remain compliant and relevant as standards evolve.

Early Access to Regulatory Updates: Collaborating with regulatory bodies to gain early access to upcoming compliance data would allow predictive models to incorporate these changes proactively. This approach would enable companies to prepare for new standards in advance, fostering a seamless transition as regulations evolve.

By exploring these future research directions, the maritime industry can enhance its operational, financial, and compliance capabilities, ultimately fostering a resilient and adaptive ecosystem. Each recommendation builds upon the foundations established in this study, emphasizing the value of continuous innovation and collaboration for a sustainable, data driven future in tanker shipping.

6.4 Conclusion

This study marks a pioneering effort to integrate advanced artificial intelligence (AI) and machine learning (ML) techniques into the operational and financial decision-making processes within the tanker shipping industry. By addressing critical challenges such as market volatility, regulatory compliance, operational efficiency, and financial sustainability, the research provides a robust framework for the maritime sector to transition from traditional, experience based practices to data-driven, technology-enhanced strategies. This transition is essential as the industry faces increasing complexity, stricter environmental regulations, and the pressures of global economic fluctuations.

Summary of Key Contributions

The study's contributions span predictive analytics, innovative financial modeling, and theoretical applications of natural language processing (NLP) to improve data accessibility, all aimed at reshaping how stakeholders in tanker shipping make informed, agile, and strategic decisions.

Integrating Predictive Modeling for Enhanced Operational Decision-Making: By employing predictive algorithms, specifically XGBoost and linear regression, the study achieves precise forecasting of essential metrics like voyage turnaround times, fuel costs, charter rates, and operational earnings. These insights support stakeholders in refining route planning, optimizing fleet utilization, and managing costs effectively. Predictive analytics enables companies to anticipate demand shifts, mitigate risks associated with price fluctuations, and make informed decisions regarding operational efficiency and resource allocation.

Sales-and-Leaseback as a Strategic Financial Model: The study underscores the potential of the sales-and-leaseback model as a financial strategy that provides liquidity, stabilizes cash flow, and supports sustainable growth. By selling assets and leasing them back, shipowners can maintain operational control while freeing up capital for reinvestment in technology, fleet expansion, or regulatory compliance. The research highlights the importance of structured education and industry guidance for implementing this model effectively, enabling stakeholders to better understand its long-term financial and operational implications.

Theoretical Exploration of NLP for Enhanced Data Accessibility: Although NLP was not implemented in the current analysis, this study introduces a forward-looking vision of how NLP-driven systems, such as Retrieval-Augmented Generation (RAG) models, could transform data accessibility for maritime stakeholders. By allowing users to interact with predictive insights through natural language, NLP integration could democratize data-driven decision-making, enabling non-technical users to leverage complex analytics through simple queries. This technology could be instrumental in bridging the gap between data and actionable insights, fostering a more inclusive, data-centric culture within the industry.

Sustainability and Compliance as Strategic Imperatives: The study highlights the growing importance of sustainability within the industry, aligning with global regulatory standards and shifting consumer expectations. Predictive models that factor in environmental data allow companies to optimize fuel consumption, select eco-friendly routes, and minimize emissions, positioning them as responsible participants in an increasingly eco-conscious market. By emphasizing the role of technology in meeting sustainability targets, this research lays the groundwork for maritime companies to reduce their environmental impact and gain a competitive edge in a regulated industry.

Practical Implications for the Maritime Industry

This research has several practical implications for stakeholders within the tanker shipping industry. It emphasizes the transformative potential of AI/ML in reshaping operational practices, financial planning, and compliance management, with each area contributing to a more resilient and sustainable maritime sector.

From Reactive to Proactive Management: Predictive analytics enables maritime companies to shift from reactive decision-making, based on past experiences and ad hoc judgments, to proactive, data-driven strategies. By forecasting market demand, fuel prices, and route profitability, companies can preemptively adjust operations to maximize efficiency and profitability. This shift reduces exposure to market volatility and enhances competitiveness, positioning companies to thrive in a fast-changing global environment.

Strengthening Financial Resilience with Sales-and-Leaseback: The study demonstrates that the sales-and-leaseback model can be a strategic financial tool for generating liquidity without compromising operational control. For maritime companies, particularly those facing high capital costs and cyclical revenues, this model provides a valuable option to maintain financial flexibility while securing assets for future use. Additionally, promoting industry-wide education and guidance on leaseback models could foster broader adoption, enabling stakeholders to leverage this financial tool effectively and confidently.

Enhancing Accessibility and Data-Driven Culture with NLP: Introducing NLP-based systems would transform accessibility to data insights, particularly for non-technical stakeholders. NLP allows different departments to query predictive insights using plain language, making complex data approachable and actionable. This democratization of data access not only improves decision-making but also fosters a data-driven culture across maritime organizations, where insights are no longer confined to technical teams but shared across operations, finance, and management roles.

Building Resilience Through Collaboration and Industry-Wide Platforms: The study's findings suggest that the tanker shipping industry can benefit from increased collaboration, particularly in areas like compliance and predictive modeling. Collaborative platforms could standardize compliance practices, streamline data sharing, and enable smaller companies to access advanced technologies that would otherwise be out of reach.

Such shared resources enhance resilience across the industry, creating a unified response to challenges like regulatory changes, environmental standards, and economic downturns.

Promoting Environmental Responsibility and Compliance: As regulatory pressures around emissions and sustainability increase, the ability to incorporate environmental data into predictive models will become essential. The industry's commitment to reducing its environmental impact is not only a compliance requirement but also a strategic differentiator that can improve public perception and attract eco-conscious clients. Emphasizing sustainable practices and investments in green technologies supports long-term resilience, ensuring that companies remain viable as global environmental standards continue to evolve.

Strategic Directions for Future Development

The findings and recommendations from this study outline a clear roadmap for the future of the tanker shipping industry. By embracing technological innovation, fostering industry collaboration, and prioritizing sustainability, the industry can position itself for sustainable growth, enhanced resilience, and operational excellence.

Embracing Advanced Technologies and Data-Driven Practices: As the maritime industry navigates an increasingly complex regulatory and economic landscape, integrating advanced technologies such as AI, ML, and IoT will be essential. These technologies provide the tools needed to anticipate challenges, optimize operations, and respond with agility to shifting market conditions. Future investment in these technologies should be coupled with a commitment to continuous learning and adaptation, ensuring that companies remain at the forefront of innovation.

Exploring the Practical Implementation of NLP and IoT Solutions: While the theoretical potential of NLP and IoT solutions was highlighted, future research and development efforts should focus on implementing these technologies within the industry.

NLP-driven systems can facilitate intuitive data interactions, allowing stakeholders to query complex data in natural language. IoT, on the other hand, enables real-time monitoring of operational metrics, supporting data-driven adjustments that enhance efficiency, safety, and compliance. Together, these technologies create a comprehensive data ecosystem, bridging predictive insights with real-time monitoring.

Fostering Industry-Wide Collaboration and Data-Sharing Platforms:
Shared compliance platforms, collaborative predictive modeling, and joint data-sharing initiatives can democratize access to advanced technology, making it more affordable and accessible for smaller companies. Such platforms offer an industry-wide approach to challenges like regulatory compliance, sustainability, and market fluctuations, fostering resilience and unity within the sector. By learning from collaborative models in other industries, maritime stakeholders can create similar frameworks tailored to the specific needs of the shipping sector.

Adapting to Evolving Regulatory and Environmental Standards: The maritime industry is at a juncture where meeting regulatory and environmental standards is both a compliance requirement and a competitive advantage. Companies should prioritize adaptability, investing in technologies and strategies that allow for continuous compliance with changing regulations. Predictive models that incorporate emissions data and environmental impact analysis will be instrumental in aligning operations with international sustainability goals, allowing companies to thrive in a market increasingly focused on environmental responsibility.

Concluding Thoughts

In conclusion, this study presents a comprehensive framework for integrating AI, predictive modeling, and innovative financial strategies within the tanker shipping industry. By shifting from traditional, experience-based practices to a data-driven approach, maritime companies can enhance operational efficiency, improve financial stability, and ensure compliance with regulatory standards. This transformation aligns with the industry's need for resilience, sustainability, and adaptability in a global market that is evolving rapidly.

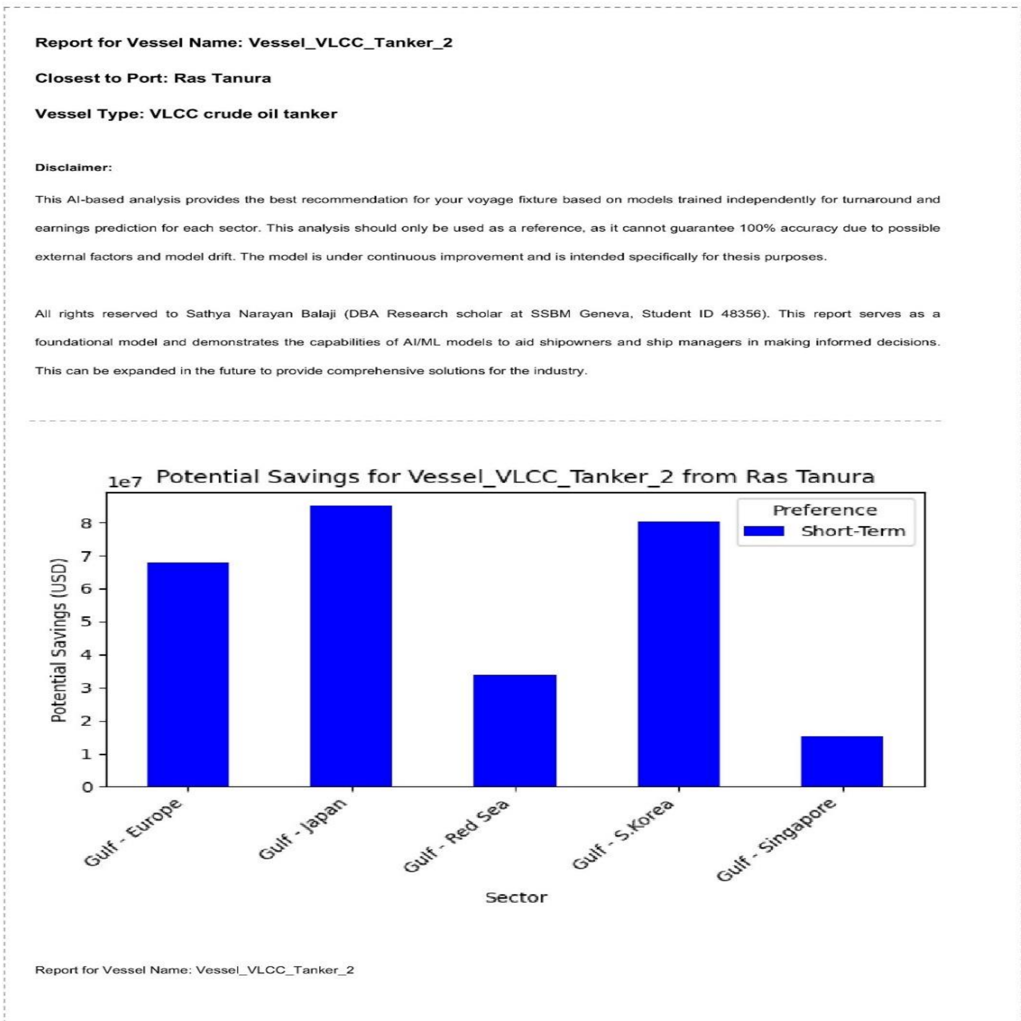
The adoption of AI-driven solutions, NLP applications, and sales-and-leaseback financial models reflects a cultural shift within the industry. It underscores the transition from traditional practices to a modern, technology-centric approach that emphasizes data accessibility, environmental responsibility, and financial resilience. As the industry embraces these innovations, it sets a new standard for excellence and adaptability, positioning itself to navigate future challenges with confidence.

Looking ahead, the maritime sector's success will depend on a sustained commitment to research, collaboration, and technological investment. The insights from this study provide a foundation for future exploration, urging stakeholders to prioritize continuous learning, regulatory adaptability, and sustainable practices.

In doing so, the tanker shipping industry can secure a competitive edge, meeting the demands of a dynamic global landscape while contributing positively to the environment and society.

6.5 (Proof Of Concept) M.L Analysis Report Output

Below is the PDF report generated by the Machine Learning (ML) model, showcasing the detailed analysis and predictions. This report provides key insights, including turnaround time and earnings forecasts, designed to aid decision-making processes within the tanker shipping industry. Addditional data to improve accuracy and comprehensiveness in future versions.



Report for Vessel Name: Vessel_VLCC_Tanker_2

Closest to Port: Ras Tanura

Vessel Type: VLCC crude oil tanker

Disclaimer:

This AI-based analysis provides the best recommendation for your voyage fixture based on models trained independently for turnaround and earnings prediction for each sector. This analysis should only be used as a reference, as it cannot guarantee 100% accuracy due to possible external factors and model drift. The model is under continuous improvement and is intended specifically for thesis purposes.

All rights reserved to Sathya Narayan Balaji (DBA Research scholar at SSBM Geneva, Student ID 48356). This report serves as a foundational model and demonstrates the capabilities of AI/ML models to aid shipowners and ship managers in making informed decisions. This can be expanded in the future to provide comprehensive solutions for the industry.

Report for Vessel Name: Vessel_VLCC_Tanker_2

Figure 16. Sector-Wise Potential Savings (POC generated ML Report)

Closest to Port: Ras Tanura

Vessel Type: VLCC crude oil tanker

Disclaimer: This AI-based analysis provides the best recommendation for your voyage fixture based on models tr
turnaround and earnings prediction for each sector. This analysis should only be used as a reference, as it cannot gu
due to possible external factors and model drift. The model is under continuous improvement and is intended specifica
All rights reserved to Sathya Narayan Balaji (DBA Research scholar at SSBM Geneva, Student ID 48356). T
foundational model and demonstrates the capabilities of AI/ML models to aid shipowners and ship managers in mal
This can be expanded in the future to provide comprehensive solutions for the industry.

Long-Term Preferred Routes:

Route	Turnaround_Time_Days	Earnings_per_Day_USD	Potential_Savings_USD
Ras Tanura to Rotterdam	41.510246	275061.15625	11417856.0
Ras Tanura to Rotterdam	41.510246	450204.56250	18688102.0
Ras Tanura to Rotterdam	42.508133	283907.84375	12068392.0
Ras Tanura to Rotterdam	41.510246	221582.78125	9197956.0
Ras Tanura to Rotterdam	43.501575	380842.65625	16567256.0
Ras Tanura to Kikuma	40.860760	545473.43750	22288460.0
Ras Tanura to Kikuma	40.860760	438128.84375	17902278.0
Ras Tanura to Kikuma	42.852600	507511.65625	21748194.0
Ras Tanura to Kikuma	41.858517	552300.06250	23118462.0

Short-Term Preferred Routes:

Route	Turnaround_Time_Days	Earnings_per_Day_USD	Potential_Savings_USD
Ras Tanura to Suez	22.400335	499444.96875	11187735.0
Ras Tanura to Suez	22.400335	476728.31250	10678874.0
Ras Tanura to Suez	23.396053	516116.68750	12075094.0
Ras Tanura to Singapore	25.139999	281925.40625	7087604.5
Ras Tanura to Singapore	25.139999	323010.59375	8120486.0
Ras Tanura to Yeosu	42.830299	437740.90625	18748574.0
Ras Tanura to Yeosu	40.840370	468802.40625	19146064.0
Ras Tanura to Yeosu	40.840370	330487.87500	13497247.0
Ras Tanura to Yeosu	39.848385	375231.53125	14952370.0
Ras Tanura to Yeosu	41.837563	333971.18750	13972540.0

Best Long-Term Route:

Figure 17. Best Long and Short route Recommendations (ML Report)

Disclaimer: This report is part of an ongoing proof-of-concept (P.O.C) and remains in development. Due to the evolving nature of the model, there may be biases or inaccuracies in the results that could affect decision-making. This model is continuously being refined to enhance reliability, address potential biases, and incorporate additional data to improve accuracy and comprehensiveness in future versions.

Vessel	Vessel_VLCC_Tanker_2
Route	Ras Tanura to Kikuma
Sector	Gulf - Japan
Turnaround_Time_Days	41.858517
Earnings_per_Day_USD	552300.0625
Potential_Savings_USD	23118462.0
Route_Distance_nm	6328.0
Anchorage_Days	2.0
At_Port_Days	2.0

Best Short-Term Route:

Vessel	Vessel_VLCC_Tanker_2
Route	Ras Tanura to Yeosu
Sector	Gulf - S.Korea
Turnaround_Time_Days	40.84037
Earnings_per_Day_USD	468802.40625
Potential_Savings_USD	19146064.0
Route_Distance_nm	6158.0
Anchorage_Days	2.0
At_Port_Days	2.0

Overall Best Route Considering Anchorage and Berth Timings:

Vessel	Vessel_VLCC_Tanker_2
Route	Ras Tanura to Kikuma
Sector	Gulf - Japan
Turnaround_Time_Days	40.86076
Earnings_per_Day_USD	545473.4375
Potential_Savings_USD	22288460.0
Route_Distance_nm	6328.0
Anchorage_Days	2.0
At_Port_Days	1.0

Figure 18. Best route Prediction (POC generated ML report)

Disclaimer: This report is part of an ongoing proof-of-concept (P.O.C) and remains in development. Due to the evolving nature of the model, there may be biases or inaccuracies in the results that could affect decision-making. This model is continuously being refined to enhance reliability, address potential biases, and incorporate additional data to improve accuracy and comprehensiveness in future versions.

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