Evaluating Revenue in Empty Containers for Repositioning and Full Export Strategy in EU Operations

MOT2910 Master Thesis Project

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MAERSK

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Evaluating Revenue in Empty Containers for Repositioning and Full Export Strategy in EU Operations

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by

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Summary

Containerized transport has emerged as a pivotal mode of transportation in global trade, which accounted for approximately 60% of total global trade volume. A core challenge within the shipping industry today is the issue of trade imbalances, which are rooted in factors such as gaps in income levels between domestic and foreign markets, variations in wage-bargaining structures, trade policies, and geopolitical tensions. The implications of trade imbalances are shown in regional surpluses and deficits. Surplus regions reflect a higher volume of imports than exports, which results in the accumulated containers used from sea transport. In contrast, deficit regions experience higher export volume than imports, which results in less containers available to transport goods due to less container input from import activities.

These imbalances significantly impact shipping companies' revenue, as they are required to meet container demand in deficit areas to capture customer demand across all regions. A commonly adopted strategy to address this challenge is empty repositioning, which involves relocating empty containers from surplus regions to deficit regions. However, this practice is associated with the trade-off of adding higher additional costs without generating direct significant revenue in the short-term for shipping companies.

Maersk, a leading player in the industry and acts as the case study for this research, also faces trade imbalance issues. Currently, Maersk prioritizes the demand from the deficit region, which is Far East (such as China), specifically Far East to Europe journey, which represents the journey with the highest revenue contribution in its operations. However, Maersk, especially the Equipment Flow team, who are in charge of planning the container allocation in European trade, wants to confirm whether their current approach is optimal or needs further improvement. This thesis project aims to confirm whether the strategy they implemented in 2023 (reflected in Alternatives 1) is better than prioritizing the containers allocation to deficit regions, which is Far East (Alternatives 2). The thesis project question is: "**How does the company's current approach to managing European exports compare in terms of revenue to prioritizing empty containers for relocation to areas with deficits?**". In general, below are the alternatives that will be evaluated in this thesis project.

1) **Alternative 1**: Maintaining Maersk's business approach as implemented in 2023, which balances fulfilling export demand from all regions while continuing to address export needs from surplus areas.
2) **Alternative 2**: Prioritizing empty container deployment to deficit regions by curtailing the full containers from Europe's outbound journey (Europe to any region, except Far East) and relocating those supposedly laden containers empty from Europe to Far East so that empty containers can be utilized as laden to fulfill demand on Far East to Europe.

The insights derived from this study are expected to contribute to a broader understanding of how shipping companies can manage their strategies in container allocation in response to trade imbalances. By examining these alternatives, the research seeks to provide actionable recommendations to address how they should allocate their containers in case of trade imbalances, ultimately supporting shipping companies in navigating this long-standing challenge more effectively.

The analysis of the alternative's evaluation shows that overall total revenue when prioritizing empty container allocation to deficit regions compared to maintaining the export level alternative shows minimal

effect due to the slight differences in both total revenues. In terms of total revenues, maintaining export level alternative's (Alternative 1) yield slightly higher total revenues. However, if we look at the range of total revenues generated in Far East after curtailment, prioritizing empty containers to deficit regions depicted (Alternative 2) slightly higher range compared to Alternative 1 with the increase on total revenue's range about 0.75%. However, this increase is not significant compared to the annual growth of revenue in the shipping industry which accounts for 2.7% per year (Cargo Shipping Market Revenue, 2024). In addition to the small increase in total revenue range in Alternative 2, the variation of total revenue in each region also increases. In the context of seasonality, the data distribution in Africa and Latin Africa shows no significant difference when performing Alternative 2. Far East and North America are affected by the seasonality due to their higher volume of trade. Amid these notable differences, seasonality does not affect the range of revenue in each region, but it makes the revenue more stable due to the nature of high contractual customer percentage in Maersk. This nature makes the demand more predictable.

Hence the answer to thesis project questions of "**How does the company's current approach to managing European exports compare in terms of revenue to prioritizing empty containers for relocation to areas with deficits?**" can be answered as below**:**

"*Prioritizing the relocation of empty containers to deficit regions has only a marginal impact on total profitability when compared to maintaining export volumes. While relocating empty containers addresses trade imbalances and reduces container deficits, the additional revenue generated from this strategy remains minimal relative to full export shipments. The primary reason for this is the lower profitability associated with moving empty containers compared to fully laden ones, particularly on routes like Far East–Europe, which show the greatest variability in potential profit*."

Objective

The primary objective of this research is to develop an adaptable simulation model on empty container allocation through evaluating two strategic approaches. The goal is to provide shipping companies with data-driven insights into container allocation alternatives, identifying which strategy is more profitable in terms of revenue generation for supporting export operations within Europe.

Approach

This thesis project employs a mixed-methods approach, combining qualitative and quantitative analyses to address the research objectives. The qualitative analysis is conducted through an extensive literature review to understand the current state and context of the shipping industry, including supply and demand dynamics, planning processes, and global trade conditions. This review will help identify critical parameters that significantly impact revenue.

These identified parameters will serve as inputs for the quantitative analysis, utilizing Monte Carlo simulation to account for the uncertainties associated with independent variables. The simulation results will be visualized using histograms and heatmaps, providing insights into each parameter's behavior and influence. The combined approach ensures a comprehensive understanding of the problem and facilitates data-driven recommendations for further strategic decision-making.

Contributions

This thesis project contributes to the development of a mathematical model to analyze each identified parameter's impact on the revenue of shipping companies, specifically addressing challenges arising from the trade imbalance issue. The model is designed to be reusable for other trade imbalance issues, enabling shipping companies to apply it whenever a trigger related to trade imbalances occurs. By inputting their data into the model, companies can leverage the model to derive actionable insights tailored to their operational context. The model is then visualized in the form of histogram and heat maps. Heat maps are well-known in natural sciences, and they are among the most used graphs in biology. Furthermore, similar approaches were established in the disciplines of engineering and information technology, as well as machine learning and geosciences, including mineral prospecting (Feltrin & Bertelli, 2019; Wilkinson & Friendly, 2009). In this thesis project, visualization in the form of heat maps plays a critical role in research within the field of logistics and transportation. Heat maps contribute to providing insights into the correlation between multiple variables, serving as a supplementary perspective to histogram analysis. This combined approach facilitates a deeper understanding of why histogram results exhibit certain patterns, enabling further exploration of the findings through heat map visualizations.

The parameters and formulas developed in this research are designed to be adaptable, allowing modifications to align with the specific requirements of individual shipping companies. This ensures that the model can generate highly relevant and company-specific results. Moreover, in the future, if shipping companies identify additional critical parameters that are not included in this research, they can incorporate these into the model as needed, enhancing its applicability and precision in addressing emerging challenges.

Recommendations

Since there will be time where prioritizing the empty containers allocation to deficit regions is inevitable, there are several approaches that can be executed:

1. Maintain 100% outbound utilization on European-to-Far East journeys as a pre-requisite to achieve higher potential total revenue in Alternative 2, as seen in the analysis. Due to their perfect correlation, an increase in outbound utilization should also result in an increase in return utilization.
2. If the minimal gaps of revenue matters, perform curtailing of outbound trade from Latin America, where curtailing has a minimal financial impact and generating higher revenue compared to curtailment from two other regions. Avoid aggressive curtailing in regions like Africa and where revenue is driven by high utilization and outbound trade volumes.

In the context of maintaining export level, several aspects need to be considered to maintain higher revenue implication as below:

1. Maintain optimum return freight rates and transit time return since both aspects influence total revenue and total revenue per day
2. Carefully determine the freight rate return and outbound of Africa, especially the outbound rates since it has a higher degree of influence on revenue outcomes.

3. Maintain optimum outbound and return freight rates in Latin America since both parameters affected the total revenue and total revenue per day.
4. Maintaining high outbound rates and low transit days (outbound and return) can improve revenue outcomes.

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1. Introduction

1.1 Background

Containerization is a significant and growing aspect of global trade in the marine industry and the global industrial structure (Van Truong Pham et al., 2000). The movement of goods across long distances is made possible through containerized transport, a vital component of global trade (Veenstra, 2005). Containerization's rise reflects global manufacturing and production opportunities. However, as global manufacturing shifts to low-cost offshore production zones in Southeast Asia, China, South America, India, and Eastern Europe, more world output is entering global trade markets. In addition, more significant amounts of international cargo are mass-produced or semi-made (Van Truong Pham et al., 2000). As A result, European and American ports have a surplus of empty containers on the Europe-Asia and Trans-Pacific trade routes, while Asian ports have significant shortages (Song and Dong, 2015). In the last decade, Asia-to-Europe container trade volume was twice to three times that of the opposite direction. Consequently, at least half of the shipments heading west to Europe were returned empty leading to increased repositioning costs, which impacts the revenue generation in shipping operations.

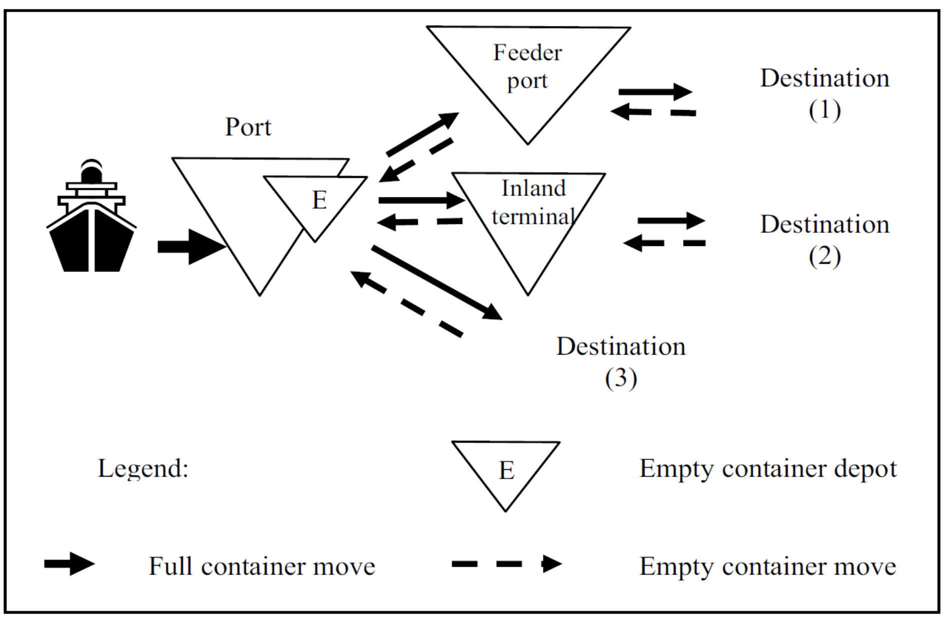

Figure 1 Empty Containers Flow Patterns (Veenstra, 2005)

In general (**Figure 1**), container logistics involves transporting a full container by sea to a regional port. There are several alternatives to the laden containers being sent to their destination. Its contents are unloaded first when arriving at the regional port, which process is known as stripping. The first alternative (3), after being stripped, is that the containers are trucked to their destination. The second scenario (1 and 2) involves moving the loaded container by rail or barge to an inland terminal, after which it is driven by truck to its ultimate location, where it is stripped. After sending the laden containers to their destination, they are returned to an empty container depot at the designated port. Usually, a truck and a coastal vessel transport it back to the port. Another option is to collect a laden container from the port terminal, deliver it straight to a stripping facility in the hinterland, and then bring it back empty to a portside depot reserved for empty containers. A solid arrow indicates the portion of the container's filled voyage, and a dashed arrow indicates the portion of the container's empty journey, as shown in **Figure 1** (Veenstra, 2005). The problem arises when empty containers accumulate in surplus regions while deficit regions face shortages.

While structural trade patterns cause container imbalances, economic downturns worsen the problem to an extreme decrease in export value growth (**Figure 2**), which impacted the global economy. Since 1950, the global economy has had four recessions: 1975, 1982, 1991, and 2009 (Kose et al., 2020).

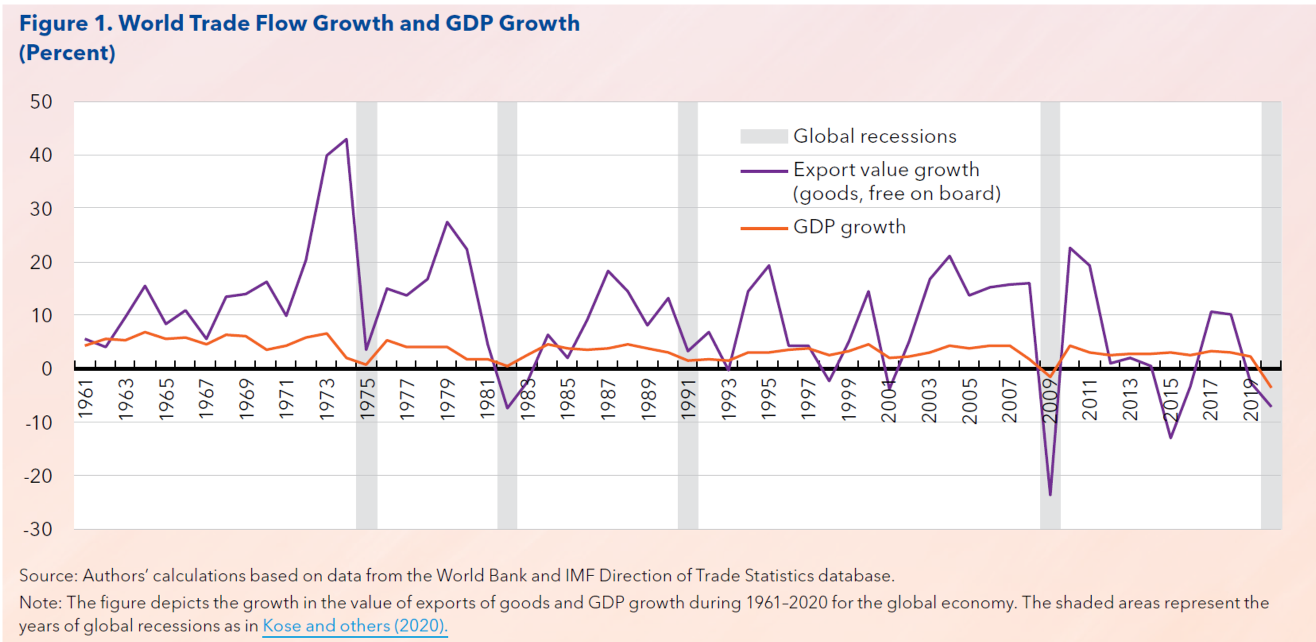

Figure 2 World Trade Flow and GDP Growth (Percent) (International Monetary Fund. Research Dept., 2022)

Economic recessions have historically resulted in notable decreases in trade volumes, resulting in an excess of empty containers in surplus regions and shortages in deficit ones. For example, the 2008-2009 financial crisis caused a dramatic decline in exports, which led to the need for empty repositioning. Similarly, the 2020 pandemic reduced world exports by 15%, producing significant trade imbalances (IMF, 2022). These fluctuations underscore the importance of adaptable container allocation strategies for ensuring profitability and supply chain resilience. The need for repositioning empty containers not only increases operational costs but also reduces the availability of containers for revenue-generating shipments, impacting overall profitability in shipping operations.

Despite these challenges, the container transport market continues to expand, driven by globalization and increasing trade volumes. Container transport has been the fastest-growing maritime transport market in the previous decade and will continue to expand for the following reasons (Janić, 2018):

i) The increasing volumes and spatial diversity of freight transport demand, coupled with its intensifying internationalization, globalization, and subsequent consolidation through containerization.

ii) The heightened competition within maritime freight transport markets necessitates liner container-shipping carriers to continuously improve the effectiveness (e.g., reliability, punctuality, safety) and efficiency of their services, particularly by deploying larger container ships and capitalizing on economies of scale.

iii) The escalating concerns regarding the environmental and societal implications of the freight transport sector, particularly its maritime transport mode and container-shipping segment.

iv) Advancement in the innovative design, materials, and manufacturing processes of container ships, alongside advancements in container-handling facilities, equipment, and seaport infrastructure.

To conclude, a core challenge in global shipping logistics is managing trade imbalances, where some regions consistently export more than they import, resulting in surplus containers in one area and shortages in others. These imbalances often arise from various economic and policy-related factors, such as fluctuations in exchange rates, differences in income levels between domestic and foreign markets, wage-bargaining structures, trade policies, and geopolitical tensions. Understanding these triggers is critical to developing adaptable models for managing container flows, as each factor introduces unique logistical needs that impact container repositioning strategies (Aleksandra, 2019; Iqbal et al., 2019; Manger & Sattler, 2019; Zhao, 2021; Feng, 2023).

1.2 Problem Statement

Containerized transport is crucial to global trade, representing around 16% of total sea tonnage and 60% of the international trade value (Castrellon et al., 2023). However, it has also highlighted a downside due to trade imbalances, with around 20% of all containers moved by sea in 2023 being empty (Madsen, 2024).

Empty container transports, in contrast with full container transports, do not produce revenue, and while completely eliminating may not be possible, reducing these costly activities would significantly cut operational expenses for transportation businesses (Braekers et al., 2011). A frequently employed solution to address this issue is the repositioning of empty containers. However, empty container relocation typically costs more than 16 billion dollars per year, which amounts to 15% of the total handling cost of containers (Liu et al., 2022). Empty container costs components (Veenstra, 2005) are explained below and are incurred by the container shipping company and its agent.

1. Handling of the empty container
2. Transportation costs of repositioning between ports
3. Transport between the port and empty container depot

Hence, the imbalance of empty containers between surplus and deficit regions leads to high repositioning costs, affecting the revenue generation of shipping companies. The key challenge is whether to sustain existing export levels or prioritize high-revenue regions for container allocation. This study aims to evaluate these strategies to determine the optimal approach for maximizing revenue.

Several actors are involved in the container flow process. Gusah et al. (2019) conducted a stakeholders and power interest analysis in the shipping market, as shown in **Table 1** and **Figure 3**.

Table 1 Stakeholder Analysis Matrix (Gusah et al., 2019)

Stakeholder	Role	Goal
Shipping Lines	Conducts the maritime stage of container movements	Profit driven
Stevedores	Operates port terminals and connects shipping lines with landside activities	Profit driven
Importers	Destination for container in the import and purchaser of containerized goods	Profit driven
Transport Operators	Organises the landside transport between the ST and the importer	Profit driven
Government	Administrative to enact policies to regulate operations	Interest driven

According to the power-interest matrix shown in **Figure 3**, the shipping lines and stevedores have the most significant power and interest in the system, as demonstrated by their capability to control other stakeholders' operations to fit their own. In contrast, the Importers/Exporters are reactive and have little influence. In this regard, shipping lines are directly impacted when trade imbalances occur, affecting their profitability. Given the shipping lines and stevedores' control over operations, their strategic decisions directly influence overall revenue generation. This highlights the importance of evaluating different allocation strategies to determine the optimum revenue-maximizing approach.

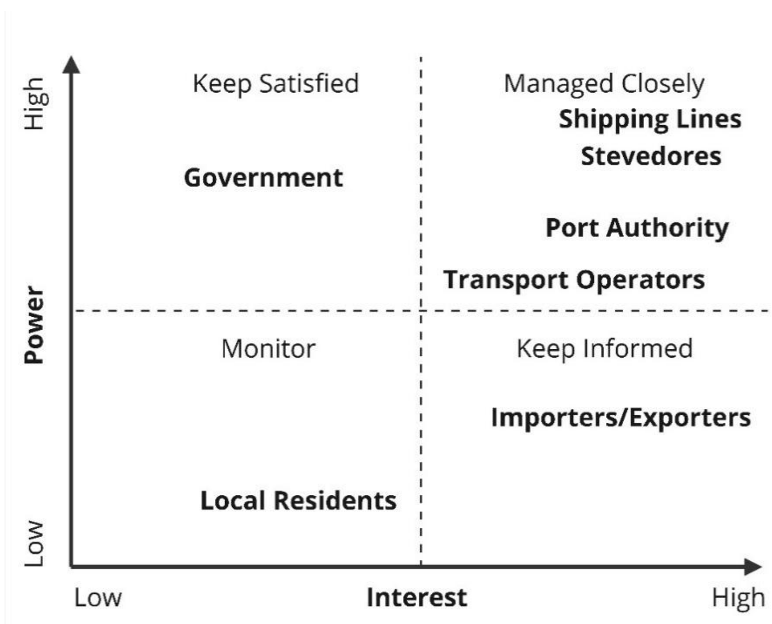

Figure 3 Power-Interest Matrix (Gusah et al., 2019)

Trade imbalances drive shipping companies to perform empty repositioning to meet container demand in deficit regions. However, as previously noted, empty repositioning incurs high operational costs, ultimately impacting revenue. To address this, shipping companies adopt various strategies to sustain revenue amid these imbalances. Some regions may experience more significant container deficits than others due to trade imbalances, yet these same regions can also yield the highest revenues.

This situation makes it critical to sustain current export levels across various regions or prioritize exports to high-revenue deficit areas by directing more empty containers to meet their demand. Prioritizing these high-revenue deficit regions would mean reallocating empty containers to support exports in these areas and aligning container availability with regional demand to enhance overall revenue.

Maersk, as a case study, is currently facing this challenge. The Far East, their largest deficit region, offers higher revenue than other regions. Currently, they are focusing on trade with these high-revenue deficit countries, though they are still determining if this strategy is optimal. Hence, Maersk proposed to evaluate two alternatives to confirm those in this thesis project:

1) **Alternative 1**: Maintaining Maersk's business approach as implemented in 2023, which balances fulfilling export demand from all regions while continuing to address export needs from surplus areas.
2) **Alternative 2**: Prioritizing empty container deployment to deficit regions by curtailing the full containers from Europe's outbound journey (Europe to any region, except Far East) and relocating those supposedly laden containers empty from Europe to Far East so that empty containers can be utilized as laden to fulfill demand on Far East to Europe.

Prioritizing high-revenue deficit regions could provide better financial returns by aligning empty container repositioning with revenue-generating demand. However, this approach may also disrupt traditional export flows from surplus regions. Therefore, this study aims to compare the financial and operational impacts of both strategies.

In this context, a simulation model plays a key role in validating existing strategies to improve stakeholders' decision-making. A deeper analysis is crucial to confirm current strategies and refine stakeholders' decision-making, enabling companies to balance their allocation of empty equipment while achieving target revenue. To validate these alternatives, a simulation model will calculate and provide data-driven insights to guide decision making for stakeholders in container shipping.

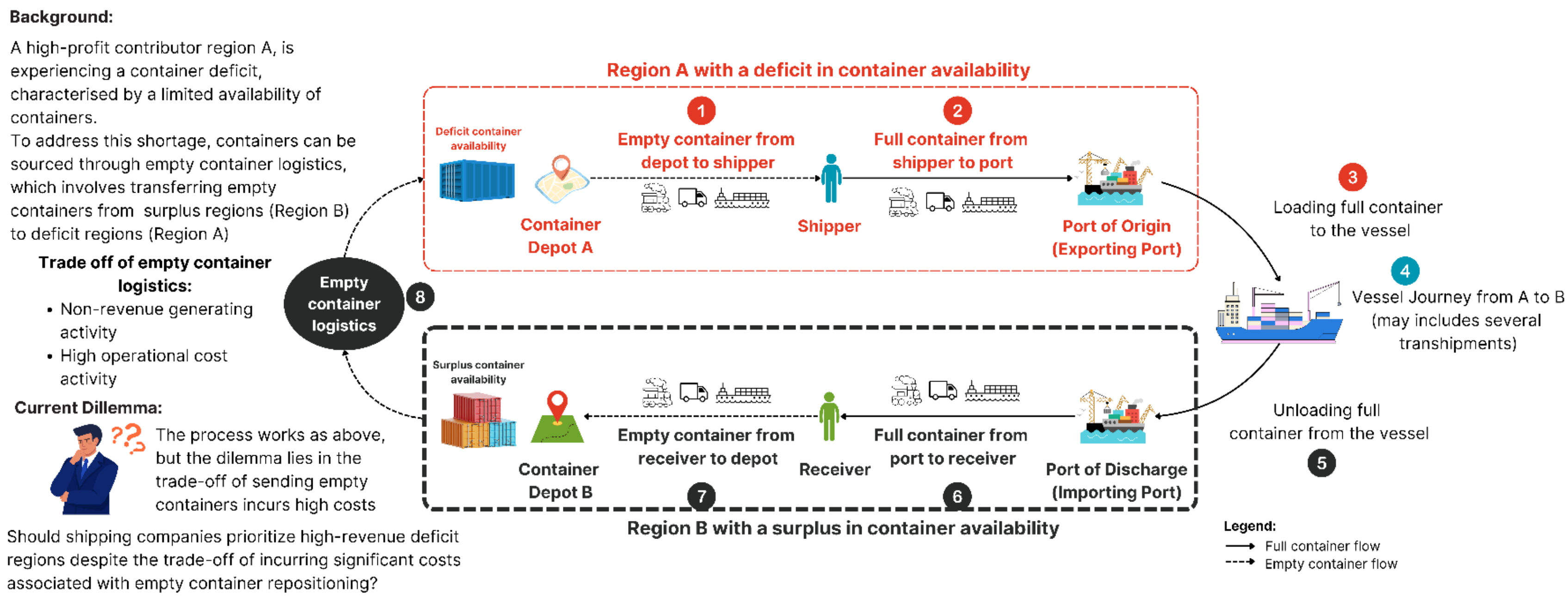

Figure 4 Visualization of Current Problem (Epstein et al., 2012)

1.3 Thesis Project Objective

The existing literature extensively discusses operational efficiency and cost management in container shipping. However, there is a lack of studies that compare the revenue implications of maintaining the current export-level strategy and prioritizing empty allocation to deficit regions.

Although theoretical models and optimization strategies for contained allocation have been extensively studied, there is limited empirical evidence on how shipping companies make real-world decisions regarding empty container allocation. Most studies focus on strategic and operational planning (Sarmadi et al., 2020) or propose mathematical models (Guo et al., 2011) but do not evaluate their practical application in revenue implication.

Hence, the **primary objective** of this research is to develop an adaptable simulation model on empty container allocation through ***evaluating two strategic approaches: 1) maintaining the current export-level strategy and, 2) prioritizing the allocation of empty containers to deficit regions through the empty repositioning process***.

The **goal** is to ***provide shipping companies with data-driven insights into container allocation alternatives, identifying which strategy is more profitable in terms of revenue generation for supporting export operations within Europe.***

1.4 Maersk- A case study company

A.P. Moller-Maersk is a leading integrated logistics company focused on connecting and simplifying supply chains. They operate globally in over 130 countries with around 100,000 employees and serve over 100,000 customers. The company aims to achieve net zero emissions by 2040 across its supply chain through innovative technologies, new vessels, and green energy solutions. The company has three main business lines: ocean, logistics and services, and terminals.

Firstly, Ocean business line facilitates global goods movement, offering customers flexibility and stability to streamline their end-to-end supply chains. It provides access to a competitive global network. Through its extensive network and digital products, Ocean offers resilient solutions and distinct value propositions, addressing diverse customer needs and fostering long-term partnerships. With a fleet of over 670 owned vessels, Ocean operates one of the largest container fleets globally, transporting nearly 12 million FFE (forty-foot equipment) annually and servicing over 475 ports worldwide.

Secondly, Maersk's Logistics & Services business line aims to address customers' supply chain needs through integrated logistics solutions powered by digital platforms. Managed by Maersk, it provides customs brokerage, supply chain management, 4PL services, cold chain logistics, and project logistics. Fulfilled by Maersk, it offers warehousing, cold storage, distribution, inland transportation, depot operations, and e-commerce logistics. Transported by Maersk includes landside transportation, air freight, less than container loads, and cargo risk management. Maersk manages over 7,800,000 sqm of warehouse capacity across 460 sites and handles 4 million FFE intermodal volumes.

Lastly, the Terminals business line, operated under the APM Terminals brand or through joint ventures, reports the performance of seven hub terminals under the Ocean segment. It supports shipping line and landside customers, contributing 75% and 25% of revenue and enhancing supply chain efficiency, flexibility, and dependability. As of 2023, Terminals managed over 27,000 vessel calls across 62 facilities in 35 countries. This strategic positioning aids customers in growing their businesses and achieving better operational outcomes (Financial Reports | A.P. Møller - Mærsk a/S, 2023).

1.5 Thesis Project Outline

The thesis project report will consist of several key sections. Chapter 1 introduces the thesis background, the company profile of the thesis project case study subject, the thesis project objective, the problem statement and the thesis outline. Chapter 2 contains information for the scope of the research, and presents the thesis project questions, design and framework. Chapter 3 identifies the global shipping market in general, discussing the shipping market, container types and demand and supply of containers. Chapter 4 analyzes the planning stages in the empty repositioning process. Chapter 5 constructs a comparative model of empty containers management strategy on supporting global exports, generates alternatives and scenarios. Chapter 6 involves model analysis and calculation. Chapter 7 presents the conclusions, recommendations, limitations and suggests areas for further research. The thesis project is executed by deploying scientific literature review or articles, semi-structured interview, and comparative analysis to provide and obtain the thesis project objective.

2. Thesis Project Methodology

2.1 Thesis Project Scope

The analysis in this thesis project is centered on region-to-region (global) trade involving Europe and its primary trade partners, the Far East, Africa, Latin America (LAM), and North America (NAM). It considers all types of containers within the Ocean business line transported on vessels but restricted to vessels operated by Maersk, both owned and chartered vessels. The research focuses on strategic and tactical planning, limited to 2023, as it best represents shipping trends observed before the pandemic.

The primary focus of this project is the strategic and tactical planning of empty container allocation in global trade, as depicted in **Figure 5**. Generic guidelines or policies for service are developed on a strategic level which then establish the criteria for tactical decision-making and tactically provide the foundation for operations and timely decisions (Braekers et al. 2011). This thesis project evaluates two alternatives: 1) sustaining the existing export-level strategy, and 2) prioritizing the distribution of empty containers to deficit regions via the empty repositioning process due to global trade imbalances. Strategic planning is crucial in deciding which lines to increase capacity or eliminate and act as a foundation when analyzing these alternatives (Crainic & Laporte, 1997). Selecting one alternative over another will affect strategic planning, as it will necessitate an adjustment of the company's existing service strategy. Tactical planning in this context which relates to empty balancing involves managing the repositioning of empty vehicles, trailers, and containers to meet forthcoming demands (Braekers et al. 2011). However, in this thesis project, we will focus on managing the repositioning of empty containers.

This study highlights global empty container repositioning, specifically addressing the maritime transport of empty containers between international ports, usually from countries having an excess of containers to those facing a shortage. Regional planning typically emphasizes empty containers that are transported overland or exchanged among importers, exporters, storage facilities, and marine terminals (Section 4.1.1 Definition).

This thesis project will not investigate network design, as it will utilize the existing trade route established by the organization to get insights from their current approach to the alternatives being evaluated. During the analysis phase, the thesis project will utilize operational data, including vessel utilization rates and overall trade throughout the trade route.

By aligning with this strategic and tactical framework, the analysis conducted in this thesis represents a comprehensive approach to medium to long-term decision-making and equipment management in global trade logistics.

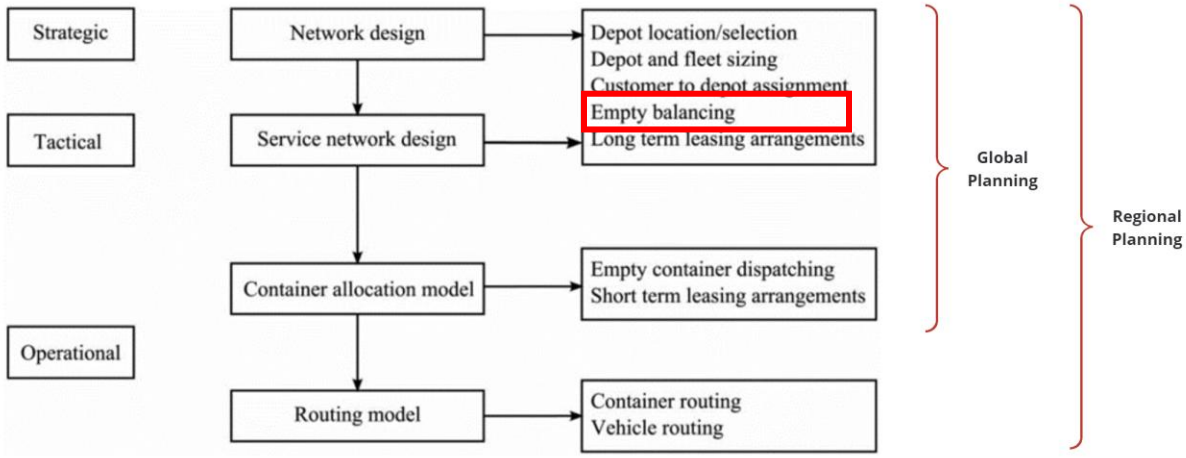

Figure 5 General Framework Empty Container Planning (Braekers et al. 2011)

In addition, due to the data limitations, the analysis will only cover revenue aspects, not the total profit in general. Since there is limited information on how to identify the cost structure in the subject company to analyze in detail the cost and profit margin.

2.2 Thesis Project Questions

This study's main research question is: "**How does the company's current approach to managing European exports compare in terms of revenue to prioritizing empty containers for relocation to areas with deficits?**"

The research will focus on several key sub-questions (SQ) to delve into this overarching question.

SQ1. *What is container repositioning, and what key factors influence the decision-making process in different regions?*

SQ2. *What revenue analysis model can be constructed to evaluate the different container allocation alternatives amid trade imbalances?*

SQ3. *How can this model be applied in real-world scenarios to enhance decision-making processes for container allocation in deficit regions?*

SQ4. *What are the revenue implications of prioritizing empty container allocation to deficit regions compared to the company's current approach?*

The thesis project will combine qualitative and quantitative methods to answer the main thesis project question: "**How does the company's current approach to managing European exports compare in terms of revenue to prioritizing empty containers for relocation to areas with deficits?**". It is expected that the thesis project will get the answer of which strategies should be implemented in case of trade imbalances, which could maintain the overall revenue by considering relevant aspects.

2.3 Thesis Project Design

The thesis project aims to determine which of these alternatives could achieve the expected balance:

1) **Alternative 1**: Maintaining Maersk's business approach as implemented in 2023, which balances fulfilling export demand from all regions while continuing to address export needs from surplus areas.
2) **Alternative 2**: Prioritizing empty container deployment to deficit regions by curtailing the full containers from Europe's outbound journey (Europe to any region, except Far East) and relocating those supposedly laden containers empty from Europe to Far East so that empty containers can be utilized as laden to fulfill demand on Far East to Europe.

Below is the explanation of how the combination of quantitative and qualitative analysis could aid in answering the main questions through the sub-research question:

SQ1. ***What is container repositioning, and what key factors influence the decision-making process in different regions?***

This sub-question will be analyzed through a scientific literature review focusing on relevant keywords found in articles and journals. The aim is to identify key factors influencing container repositioning decisions, such as logistics costs, trade imbalances, port infrastructure, economic indicators, and external disruptions. Insights from this review will contribute to a comprehensive understanding of container repositioning and serve as the foundation for selecting parameters to include in the revenue analysis model addressed in SQ2.

SQ2. ***What revenue analysis model can be constructed to evaluate the different container allocation alternatives amid trade imbalances?***

This sub-question aims to develop a revenue analysis model incorporating the variability of the key parameters identified in SQ1. To construct the model, the formula for each analyzed parameter must be defined, independent and dependent variables must be identified, and data distributions for independent variables must be established to facilitate the Monte Carlo simulation process deployed in SQ3.

SQ3. ***How can this model be applied in real-world scenarios to enhance decision-making processes for container allocation in deficit regions?***

The model developed in SQ2 will be applied to real-world data to address this sub-question. The method used will be Monte Carlo simulation, a robust tool for decision-making in revenue analysis due to its ability to model variability and unpredictability inherent in real-life scenarios. This method allows for the assessment of a wide range of possible outcomes by simulating numerous scenarios and has already been implemented in various fields such as financial, healthcare, engineering, etc. (Fabianová et al., 2023; Wu et al., 2000; Nofri et al., 2020).

This application will provide actionable insights for container allocation decisions and help identify situations where the model can be most beneficial, thus supporting strategic planning for deficit regions. The process involves collecting generalized real-world data and inputting it into the Monte Carlo simulation model created in SQ2. The simulation will then be run, and revenue outcomes for different container allocation alternatives will be analyzed.

SQ4. ***What are the revenue implications of prioritizing empty container allocation to deficit regions compared to the company's current approach?***

The outputs from the Monte Carlo simulation will be analyzed and visualized through histograms and heatmaps to answer this sub-question. This analysis will provide a visual and data-driven comparison of the revenue implications between prioritizing empty container allocation to deficit regions and the company's current strategy. Such a comparison will enable decision-makers to refine or adopt new allocation strategies that align with revenue goals. Histograms will show the distribution of key parameters across different regions and scenarios, while heatmaps will highlight correlations between these parameters within each region and scenario. These visualizations will offer comprehensive insights into revenue variability and the influence of key parameters, aiding strategic decision-making.

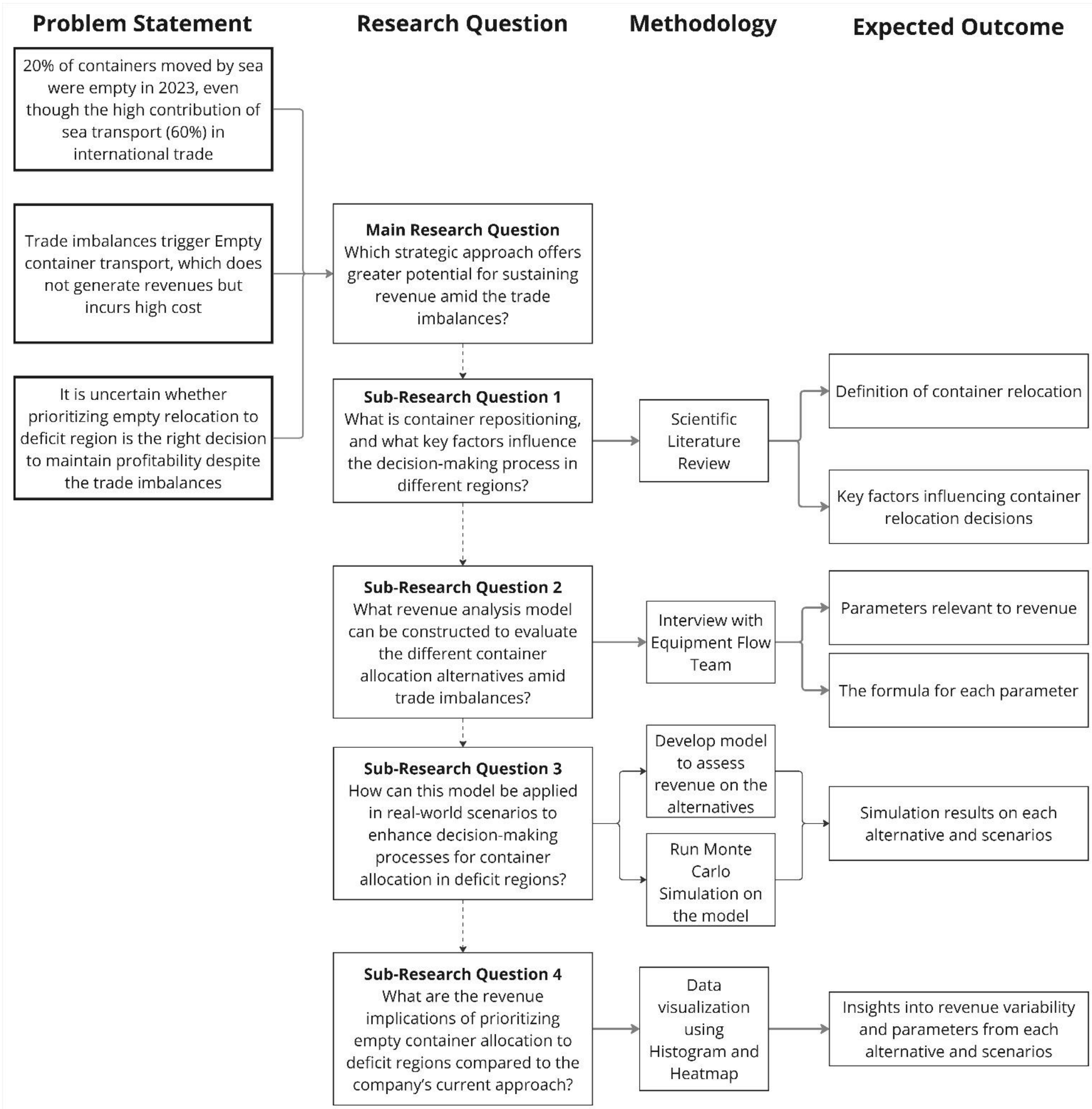

Figure 6 Summary of Thesis Project Design

2.4 Thesis Project Framework

This thesis project consists of 3 main phases in order to answer the main question and obtain the expected outcome. Those 3 phases are 1) conceptual design, 2) data collection, and variable identification, and lastly, 3) model design, simulation, and analysis. In the conceptual design, a scientific literature review and interview with the equipment flow team will be utilized. The same approach will be conducted to perform the data collection and variable identification. In the last phase, all the identified parameters relevant for revenue implications and their formulas will be simulated in a Monte Carlo simulation model based on their respective data distribution with 500 iterations. The result of those iterations will be visualized into a histogram and heatmap diagram to obtain insight from the determined alternatives and scenarios to lead to the expected outcome. The approach and method are further presented in **Figure 7**. **Sub-question 1** will be answered in the **conceptual design phase**. **Sub-question 2** is answered when performing the **second** and **third phase**, which are "Data Collection and Variable Identification" and "Model design, simulation and analysis". Lastly, **phase three** of "Model design, simulation and analysis" will aid to answer **Sub-question 3** and **4**. Conclusion will be derived after performing all the phases and to answer the main research question.

Histogram and heatmap are valuable tools for different purposes in data analysis, helping us understand the distribution and relationships within the dataset.

1. Histogram

A histogram (GeeksforGeeks, 2024) is a graphical representation that displays the distribution of a dataset by dividing it into intervals (or bins). Each bar in a histogram represents data points' frequency (count) within a specific interval. The histogram helps in understanding the distribution of a variable. It shows whether the data is spread out evenly or clustered, skewed to one side, or has unusual patterns like outliers. Below is an explanation of how to interpret the data:

a. A symmetric histogram suggests that the data is typically distributed.
b. A skewed histogram indicates an asymmetric distribution, which could point to underlying factors affecting the data.
c. Outliers may show up as isolated bars far from the central cluster.

2. Heatmap

Heat maps are an innovative visualization that exposes both row and column hierarchical cluster structures in a data matrix. Each rectangular tile is tinted on a color scale to indicate the data matrix element's value. The rows (columns) of the tiling are organized so that similar rows (columns) are close together (Wilkinson & Friendly, 2009). Heat maps are an example of visualization on multivariate analysis.

Multivariate analysis (MVA) is a set of statistical approaches that focus on combining several variables to extract or emphasize significant underlying processes. It is derived from the desire to analyze structure in data. By definition, MVA analyzes many variables. Thus, the concept of statistical correlation (an indicator of how two or more variables relate to one another) is strongly embedded in multivariate approaches. Since the analysis in this thesis project will require many parameters to be analyzed, the knowledge of a dataset can be greatly enhanced if we can examine the relationships of variables at different degrees of depth in a multivariate space (Feltrin & Bertelli, 2019). It helps to identify pairs of variables that are positively or negatively correlated, which can reveal underlying patterns or associations. The color scale ranges from dark colors for strong positive correlations to light colors for weak correlations, with negative correlations often represented in contrasting colors.

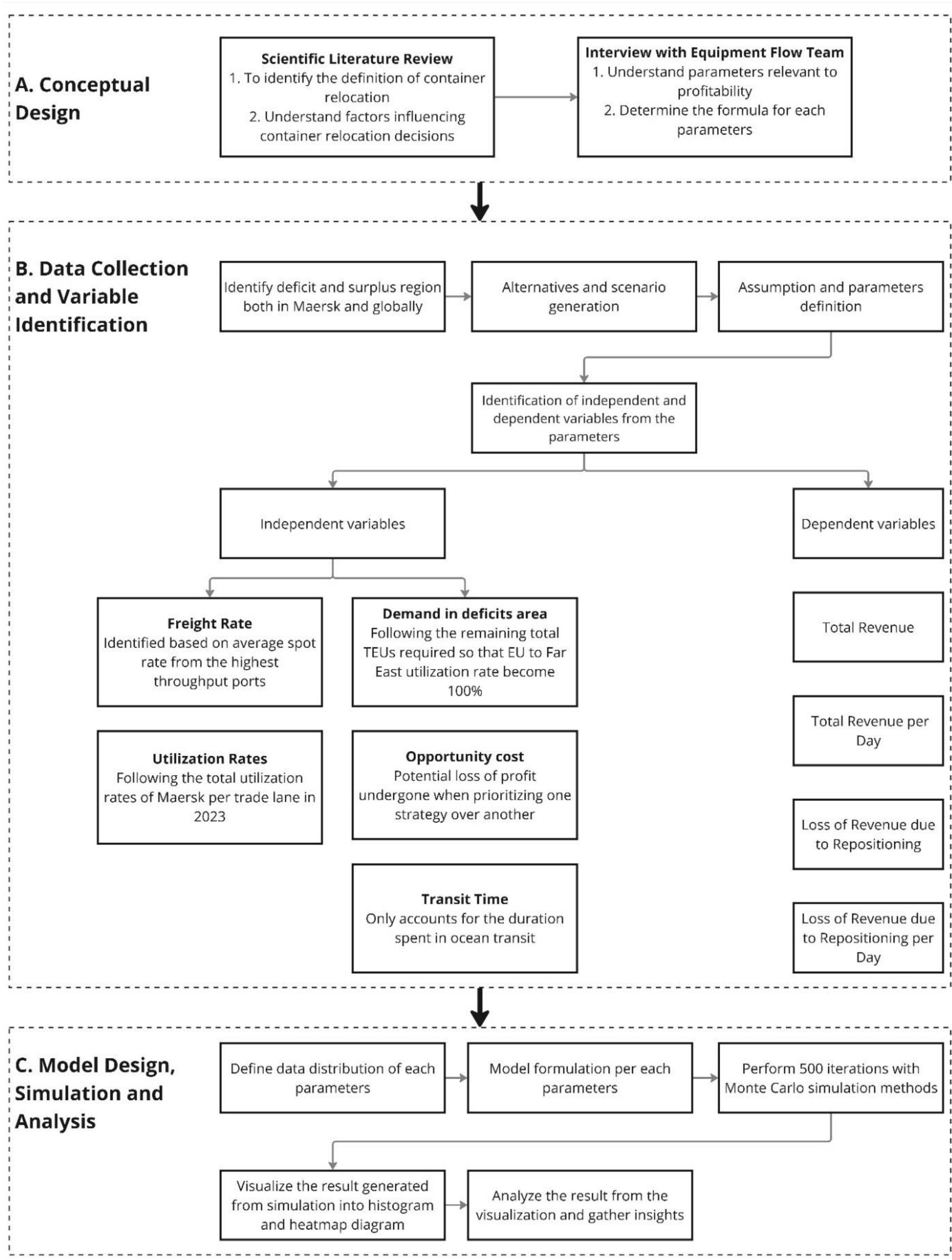

Figure 7 Summary of Thesis Project Framework

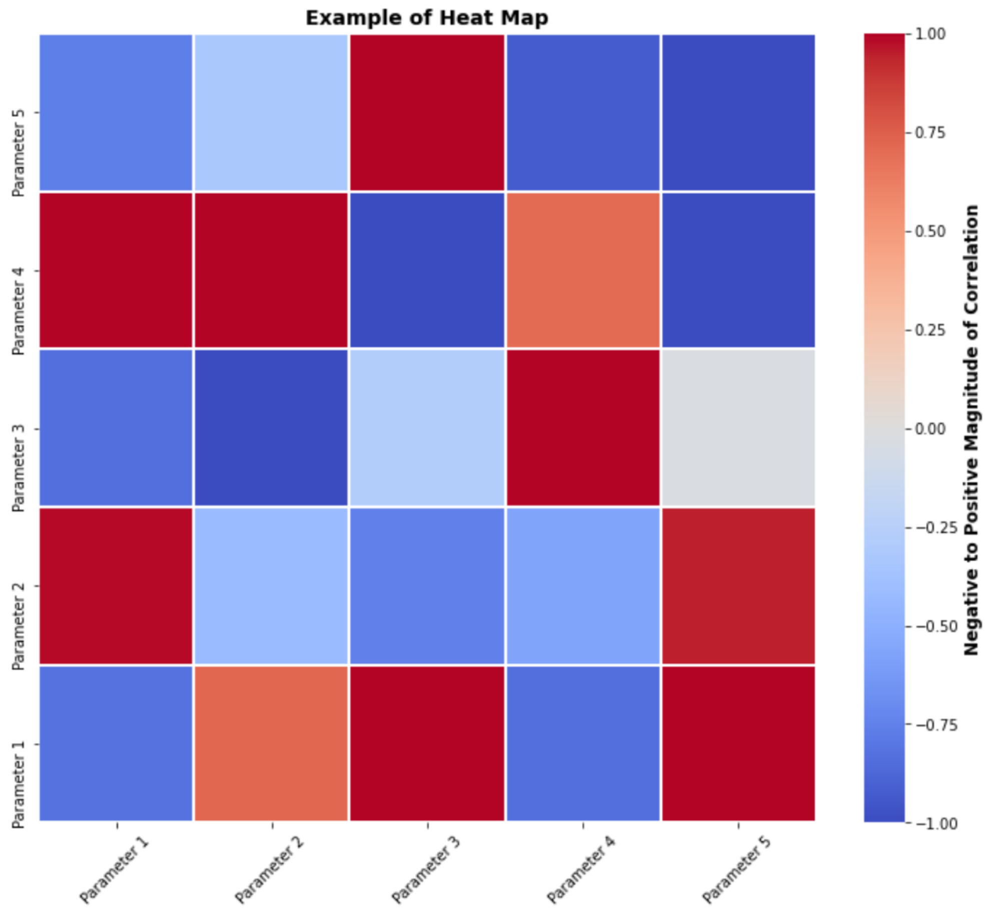

Figure 8 Example of Heat Map

In this thesis project, **Figure 8** represents the type of heat map to be used in the analysis. Positive and negative correlations are depicted with contrasting colors. As the color becomes darker, it indicates a strong negative correlation (values ranging from -1 to 0 on the color scale). Conversely, when the correlation is positive, the color shifts to a contrasting shade, with darker tones signifying a strong positive correlation (values ranging from 0 to 1 on the color scale). Below is the explanation of how to interpret the data (Rook, 2024):

a. Strong Correlation (between 0.70 and 1.00)
b. Moderate Correlation (between 0.30 and 0.69)
c. Zero to Weak Correlation (between 0.00 and 0.29), little to no relationship between the variables.
d. Positive correlation is when the variable sign is positive; as one variable increases, the other tends to increase as well.
e. Negative correlation is when the variable sign is negative; as one variable increases, the other tends to decrease.

In addition, data confidentiality is important in this thesis project. Due to that, some confidential data of Maersk, which will be used for modeling and simulation purposes, cannot be disclosed. The parameters that will be subject to generalization are Maersk container trade amount in 2023 per trade lane, freight rate, demand in deficit area and transit time. Generalization will be performed in phase "B. Data Collection and Variable Identification" and further explained in Sub Chapter 5.4 Model Design and Development.

3. Global Shipping Market

3.1 Shipping Market

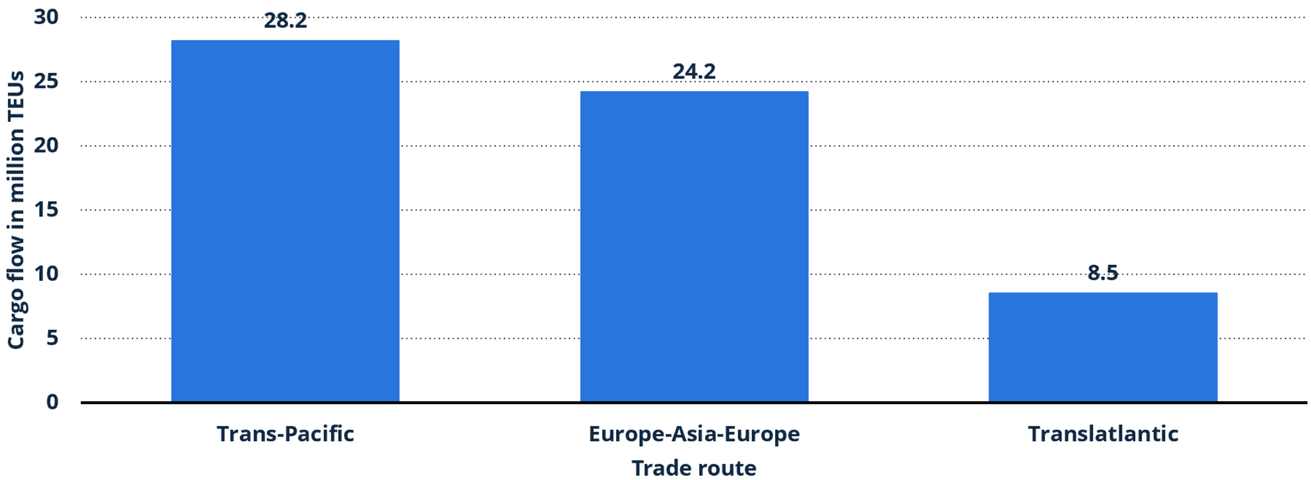

Figure 9 Global Shipping Trade Route (Statista, 2024)

According to Statista (2024), there are three primary routes for global trade: the Trans-Pacific, Europe-Asia-Europe, and the Translantic (**Figure 9**). Trans-Pacific and Europe-Asia-Europe, the two busiest routes in the world, handled 28.2 and 24.2 million TEUs, respectively. The Trans-Pacific route connects ports on the West Coast of North America, including Los Angeles and Long Beach, with ports in East Asia, predominantly in China, Japan, and South Korea. It connects East Asia's growing manufacturing hubs, mainly China, to the consumer-oriented markets of the North America's West Coast, primarily the United States. The Transpacific route is essential in worldwide trade by allowing the transit of diverse items, such as electronic devices, apparel, industrial equipment, cars, and various industrial goods. The route includes significant waterways such as the Strait of Taiwan, the South China Sea, and the vast Pacific Ocean. The Panama Canal is critical in facilitating major trade between Asia and the United States, and the Asia-East Coast US route serving as the primary trading route for ships passing through the canal (Shipadmin, 2024).

Major ports in Asia, such as Shanghai, Singapore, and Busan, are connected to ports in Europe, like Felix Stowe, Hamburg, and Rotterdam, by the Europe-Asia-Europe route. This commerce route transports various goods, including advanced electronics, garments, bulky industrial equipment, and vehicles. The Suez Canal is at the center of this route, a remarkable technical achievement offering marine vessels a shortcut between the Mediterranean Sea and the Red Sea, notably shortening transit durations and enhancing commercial efficient operation. The canal spans 193 kilometers, or roughly 120 miles, between the cities of Port Said in the north and Suez in the south (Shipadmin, 2024).

Lastly, transatlantic routes connect ports in Europe, such as Antwerp, Southampton, and Bremerhaven, with ports in North America, such as New York, Norfolk, and Savannah. It supports numerous industries and trade sectors by facilitating the movement of commodities and goods between North America and Europe (Saghari, 2023). This maritime corridor supports the transit of a wide range of goods, including cars, industrial equipment, electronic devices, and chemicals. This route is also connected with various major waterways, including the North Atlantic Ocean and the English Channel, which connects the North Sea to the Atlantic Ocean and divides the United Kingdom from the European continent. The Channel of England functions as an access route for approximately 500 vessels daily, covering a distance of about 560 kilometers (350 miles). For example, the Strait of Dover, the shallowest part of the Channel of England, is utilized by approximately 400 ships each day. This pathway was critical to New World commodity commerce, including tobacco, cotton, and sugar, which had a tremendous impact on European economies and lifestyles (Shipadmin, 2024).

3.2 Container Types

Various container types are currently utilized in maritime freight transportation (**Table 2**). The study will concentrate on the flow of empty containers, particularly standard or dry cargo containers.

Table 2 Container Type (Ligteringen, 2021)

Container Type	**Size**	**Description**
Standard container 	20 ft, 30 ft, 40 ft and their High-Cube Versions	Standard container with end doors, sidewalls, bottom, and full steel box construction. Often referred to as a dry van or dry cargo container.
Hardtop-Container 	20 ft, 40 ft and 40 ft High-Cube Version	Standard container with a steel roof that may be removed. Utilized for tall or large loads that are loaded from the top or side.
Ventilated-Container 	20 ft	Particularly for freight that requires circulation.
Refrigerated-Container 	20 ft, 30 ft, 40 ft, and 45 ft, and their High-Cube and pallet-wide versions	An electrically powered device integrated within the structure provides cooling. During land transportation, power is provided by "clip-on" diesel generators or through electrical grids on board or ashore.

Container Type	Size	Description
Open-Top-Container 	20 ft and 40 ft	Accompanied by a detachable tarpaulin. Especially for freight that is over height. Loading from either side or the top.
Flat rack 	20 ft, 40 ft, and 40 ft High-Cube Version	If huge items of cargo cannot fit within a box, flats (a bottom structure with corner castings) are used if they meet the size and payload requirements.
Platform 	20 ft and 40 ft	Particularly for large and heavy loads.
Tank Container 	The standard length is 20 ft; other lengths are available.	These containers must be kept apart from the others in the storage yard with sufficient safety precautions in case they contain dangerous materials. For example, while transporting liquids, which includes food: - Petrochemical products - Alcohol - Fruit juices - Edible oils - Food additives

3.3 Shipping Route

A route consists of two endpoints: the head-end port, the tail-end port, and several intermediate calling ports. The path from the head-end port to the tail-end port is known as the outbound journey, while the return path is called the inbound journey. Each segment of the trip, known as a leg, links two consecutive calling ports. **Figure 10** illustrates an example of such a route, where port 1 serves as the head-end port and port 5 is the tail-end port, with ports 2, 3, and 4 acting as intermediate calling points. Legs 2-4 represent the segment connecting ports 2 and 4 on the outbound journey (Takano & Arai, 2011).

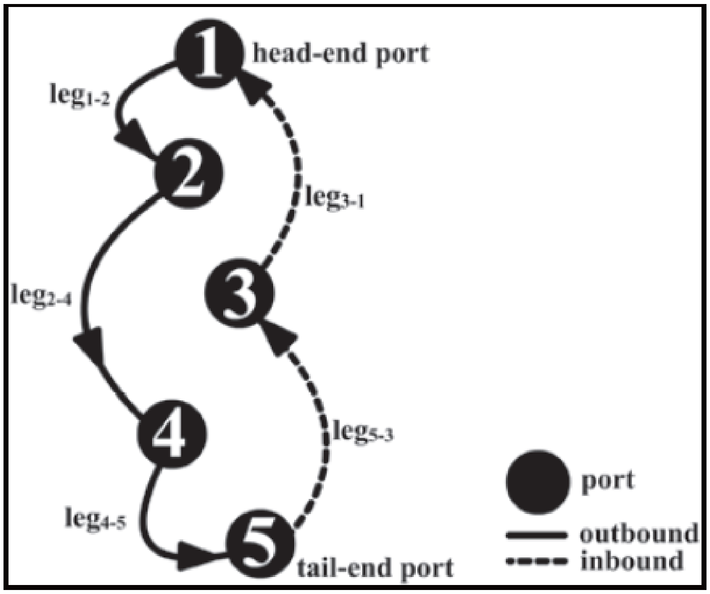

Figure 10 Example of Container Route Network (Takano & Arai, 2011)

Expanding upon this concept, the following examples of actual Maersk shipping routes provide practical illustrations of these routing principles. As illustrated in **Figure 11**, the route starts at key European ports, such as Hamburg, Antwerp, and London Gateway, which function as the head-end segment of the route. The journey then progresses through intermediate ports in the Middle East, such as Jebel Ali and Abu Dhabi, before ending at the tail-end ports in Asia, including Nansha New Port and Shanghai. This route represents the structure of an outbound journey, transitioning sequentially through intermediate ports before reaching its final destinations in Asia.

As depicted in **Figure 12**, this route originates at primary tail-end ports in Asia, such as Shanghai, Ningbo, and Yantian. The journey proceeds through intermediate ports, including Tanjung Pelepas and Colombo, before continuing through the Middle East. The inbound journey ends at major European ports, such as Le Havre, Antwerp, and Felixstowe, which serve as the head-end section of the route. This example illustrates the reverse flow of shipping logistics, connecting the tail-end ports in Asia to the head-end ports in Europe.

Specific terms are also used in shipping operations to describe the inbound and outbound journeys, known as headhaul and backhaul. Headhaul refers to the route traveling from the origin to the destination, which is typically more profitable, with higher shipping rates, a more comprehensive range of outbound options, and more favorable conditions for carriers. In contrast, backhaul refers to the return journey along the same route, which usually sees lower demand and generates less revenue due to reduced freight shipping rates. This often leads to an increased likelihood of empty container trips, prompting carriers to negotiate prices rather than sail with empty loads (Terán, 2023). If we look back at the example of Maersk's shipping route, Asia serves as the head haul since that region provides higher profit compared to Europe. Hence, Europe serves as the backhaul route.

Effective decision-making regarding container flow becomes critical to ensure efficient shipping operations and manage imbalances between supply and demand, especially during the backhaul phase, when empty container trips are more likely. This is where the process of monitoring and managing empty containers comes into play.

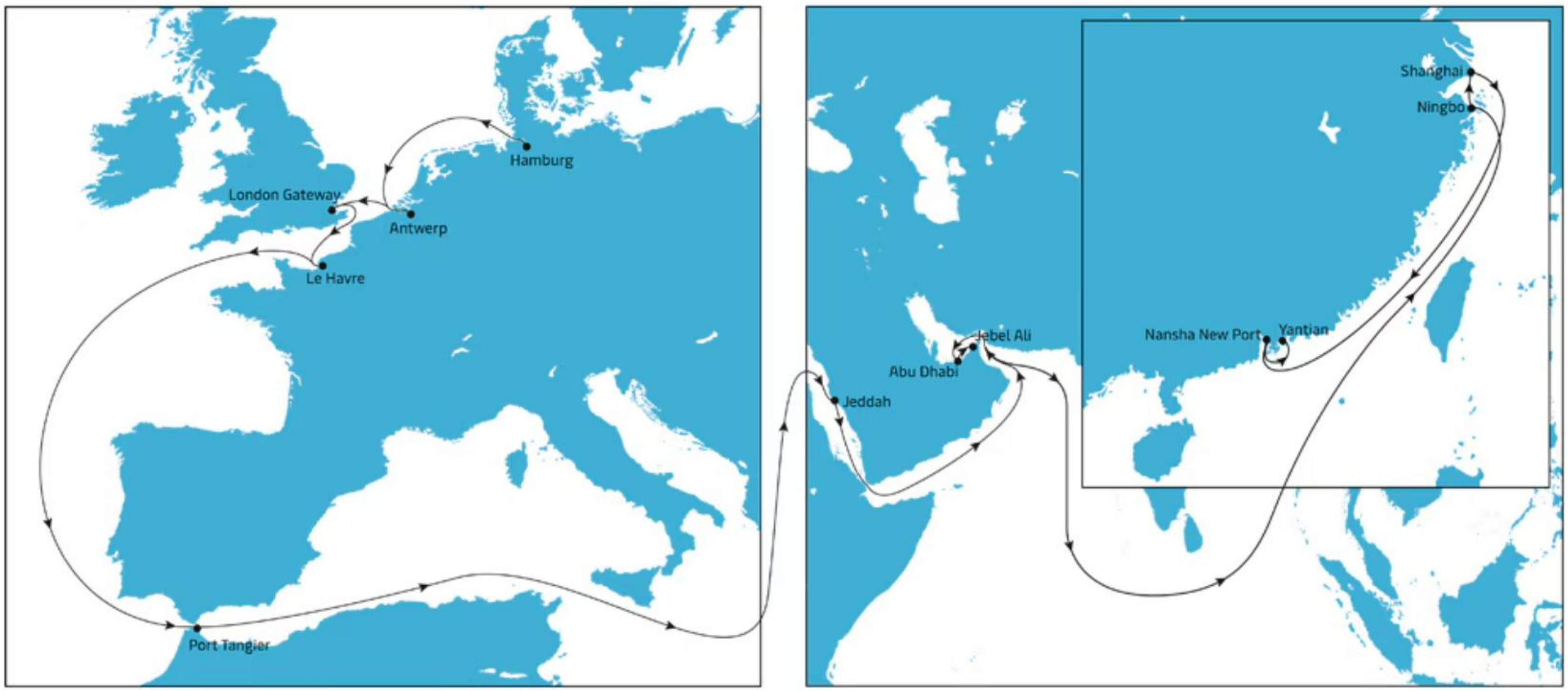

Figure 11 Example of Maersk Shipping Route from Europe to Asia (AE7 Eastbound, 2024)

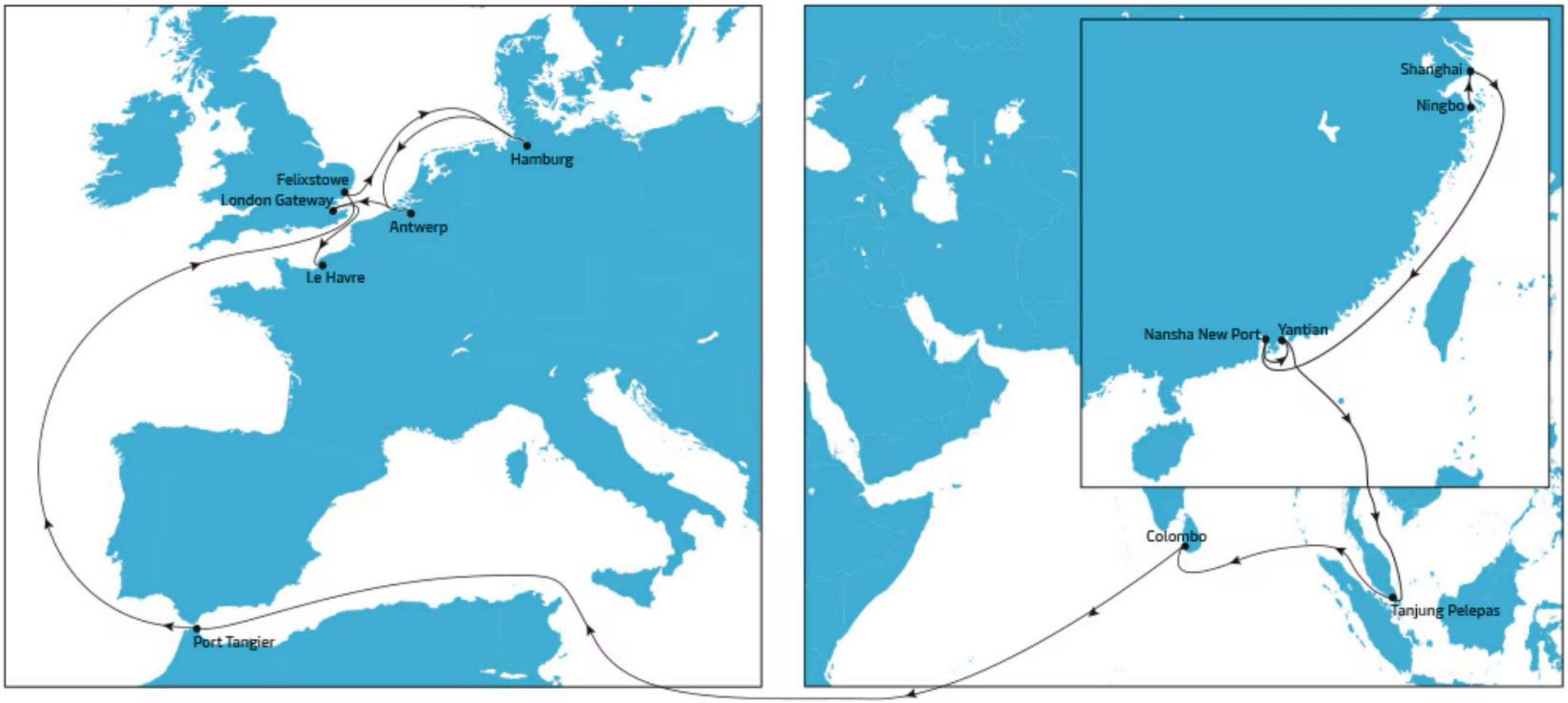

Figure 12 Example of Maersk Shipping Route from Asia to Europe (AE7 Westbound, 2024)

3.4 Demand and Supply of Containers

The shipping industry provides various transportation solutions to fulfill the distinct needs of other consumers. These services are divided into three major segments: liner, bulk, and specialized shipping, each serving different types of cargo with unique operational structures. **Liner shipping** focuses on small parcels of general cargo, including manufactured goods and minor bulk commodities like barley and steel. It is highly transaction-intensive, with a containership managing between 10,000 and 50,000 transactions annually. Liner services emphasize speed, reliability, and high service levels, as they often support integrated production operations. Although cost is critical, the volume of transactions and customer service demands drive pricing structures, often through negotiated service agreements.

Bulk shipping, on the other hand, handles large homogeneous parcels of raw commodities, such as coal ash, coal, and grain. Bulk vessels typically complete six voyages yearly, each involving a single cargo. As a result, the yearly earnings depend on just a few discussions. Bulk shipping operates with low service levels, focusing on minimizing costs while ensuring safe transport. This leads to lower operational overhead than liner shipping, as fewer organizational resources are needed.

Specialized shipping bridges the gap between bulk and liner segments, transporting complex cargoes like motor vehicles, chemicals, refrigerated goods, forest products, and liquefied gas. Specialized shipping handles more transactions than bulk but fewer than the liner, with vessels managing 400 to 600 parcels annually, often under long-term contracts of affreightment (COAs). Operators make investments in specialist ships and provide greater levels of service while working with shippers to improve logistics and optimize distribution systems.

While these divisions differ in both the value and the quantity of goods and service expectations, they overlap in specific markets and compete for cargo including forestry goods and chilled commodities. Companies sometimes operate across multiple sectors, and investors often shift between segments when they see profitable opportunities. Despite their distinct roles, these segments interact and compete, particularly for high-value and minor bulk cargoes (Stopford, 2009).

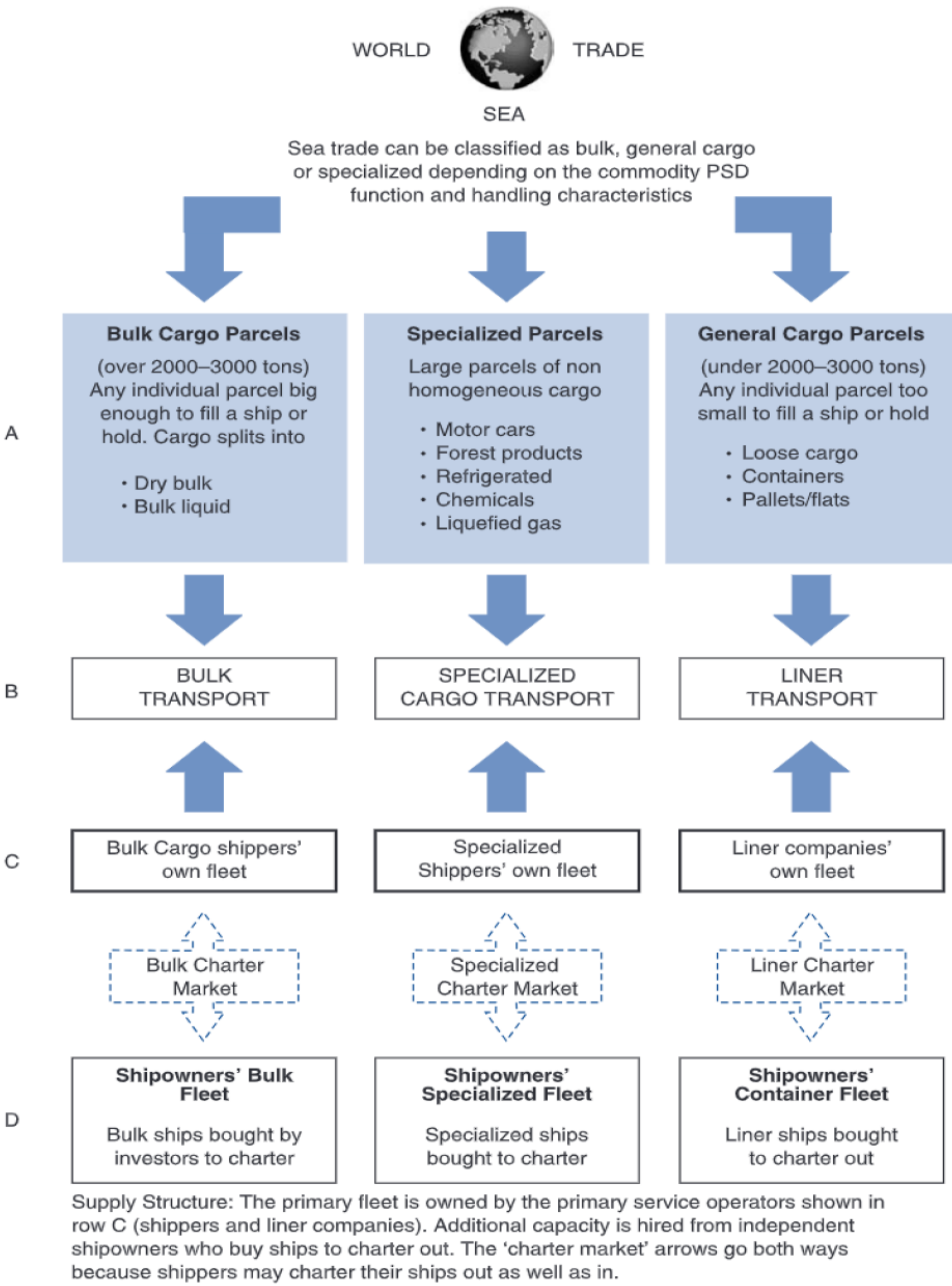

Figure 13 The Sea Transport System – Cargo Demand and Three Shipping Market Segments (Stopford, 2009)

Determining the tonnage of bulk, specialized, and general cargo shipped by sea is challenging due to the limitations of commodity trade statistics. These data do not specify how commodities are transported; many goods can be shipped by more than one segment. For instance, small parcels of steel might be containerized, while larger volumes could be transported in bulk. While some commodities, like iron ore, are typically shipped in bulk and others, like machinery, as general cargo, many, such as steel and forest products, fall into both categories. This lack of detailed cargo-type data complicates accurate analysis for shipping economists (Stopford, 2009).

The different segments of the shipping industry (liner, bulk, and specialized) each face unique operational challenges driven by the type of cargo they transport, and the service levels required. However, beyond these structural differences, the shipping industry is shaped by broader economic forces that influence demand and supply. Understanding how these forces interact is crucial to grasping the fluctuations in freight rates and overall market behavior.

3.5 Demand and Supply Interactions

The shipping market operates through a dynamic interplay of supply, demand, and freight rates, influenced by various economic and logistical factors. Demand for sea transport is driven by five key variables, as shown in **TABLE 3**, 1) the world economy, 2) seaborne commodity trades, 3) average haul, 4) random shocks, and 5) transport costs. Supply, on the other hand, is shaped by 1) the size of the world fleet, 2) fleet productivity, 3) shipbuilding production, 4) scrapping and losses, and 5) freight revenues. These variables interact through three components: demand, supply, and the freight market, which regulates cash flow between sectors (**Figure 14**).

Table 3 Ten variables in the shipping market model (Stopford, 2009)

No	Demand	Supply
1	The world economy	World fleet
2	Seaborne commodity trades	Fleet productivity
3	Average haul	Shipbuilding production
4	Random shocks	Scrapping and losses
5	Transport costs	Freight revenue

At the heart of the demand module (Module A of **Figure 14**) are cargo shippers, who determine trade patterns and negotiate freight rates, while shipping investors, including private shipowners and more giant corporations, drive the supply side by ordering new ships and scrapping old ones. The balance between supply and demand constantly fluctuates, with freight rates adjusting accordingly. When demand exceeds supply, freight rates rise, encouraging shipowners to invest in more ships. However, these new ships take time to enter the market, creating a lag in supply adjustments.

Conversely, when supply (Module B of **Figure 14**) exceeds demand, freight rates drop, forcing shipowners to sell or scrap ships to reduce capacity. This cyclical supply and demand imbalance pattern leads to irregular peaks and troughs in the market. Demand is highly volatile and unpredictable, while supply adjusts more slowly, amplifying even slight imbalances. As a result, steady earnings are rare in the shipping industry.

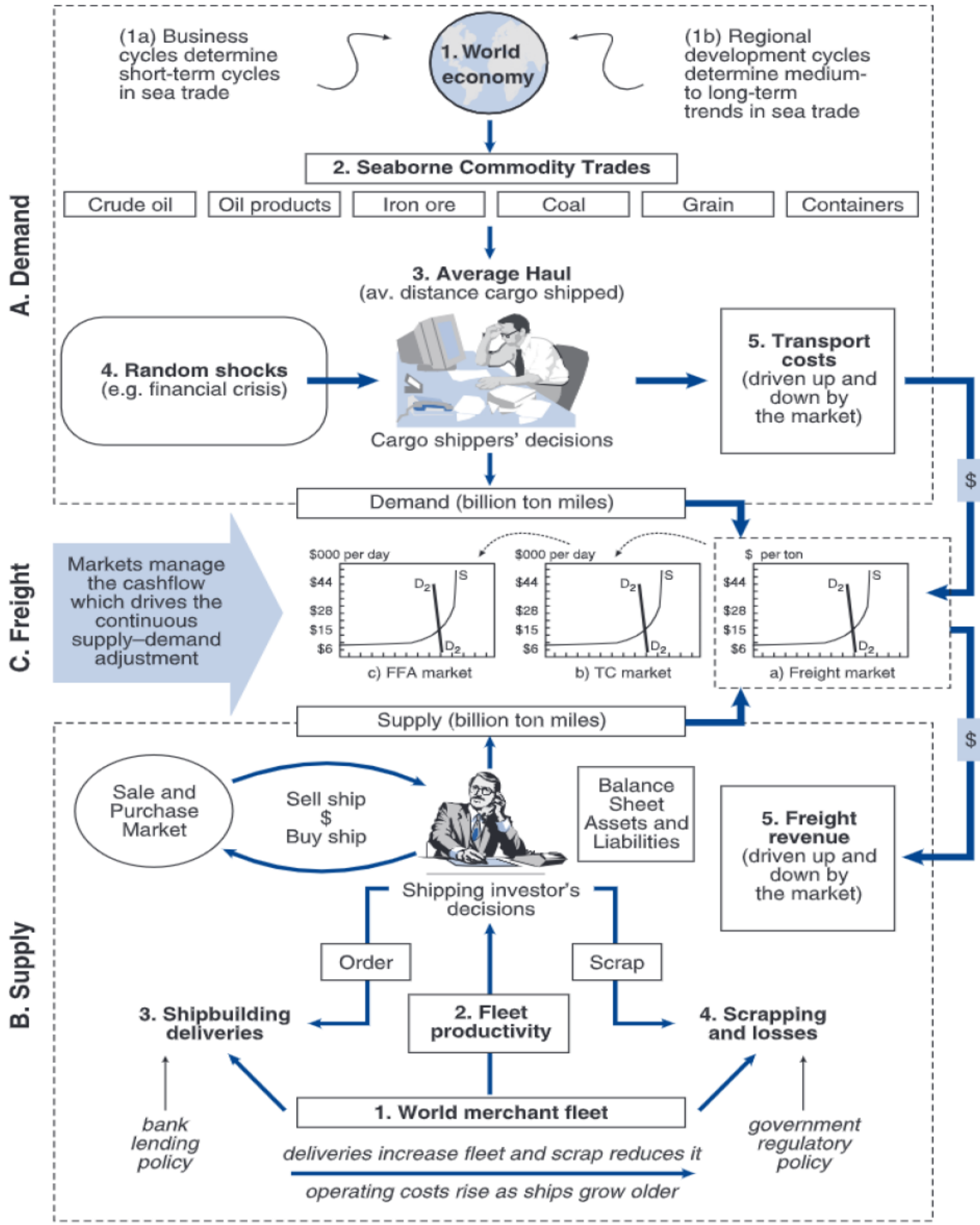

Figure 14 The Shipping Market Supply and Demand Model (Stopford, 2009)

Human factors also play a significant role. Psychological influences, such as market rumors or panics, can cause significant short-term fluctuations in freight rates (Module C of **Figure 14**), making mathematical models inadequate to capture market behavior fully. Ultimately, the market's primary function is to coordinate supply and demand growth in the complex global shipping industry (Stopford, 2009).

3.6 Sub-Conclusion

Globally, there are three primary shipping trade routes: the Trans-Pacific, Europe-Asia-Europe, and Transatlantic. Each of these routes specializes in transporting distinct types of goods. The transport of cargo involves using various container types, selected based on the specific nature of the goods being shipped. In maritime shipping, certain terminologies describe the direction and profitability of routes. The segment of a route from the head-end port to the tail-end port is called the outbound journey, while the return leg is termed the inbound journey. Furthermore, the terms headhaul and backhaul denote the direction of travel and associated revenue potential. The headhaul represents the journey from the origin to the destination, typically yielding higher profits. At the same time, the backhaul refers to the return journey, which generally experiences lower demand and generates less revenue.

The shipping industry accommodates diverse transportation needs based on cargo types, including liner, bulk, and specialized shipping services. However, accurately determining the tonnage of bulk, specialized, and general cargo transported by sea remains complex due to the limitations inherent in commodity trade statistics. These datasets often do not specify the modes of transportation used, and many goods may be shipped across multiple shipping segments.

Understanding the interplay between supply and demand within the shipping industry is crucial for analyzing fluctuations in freight rates and broader market dynamics. The demand for sea transport is influenced by five principal factors: 1) the world economy, 2) seaborne commodity trades, 3) average haul, 4) random shocks, and 5) transport costs. Conversely, the supply of maritime transport services is shaped by several variables, including 1) the size of the world fleet, 2) fleet productivity, 3) shipbuilding production, 4) scrapping and losses, and 5) freight revenues.

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4. Planning Stages in the Empty Repositioning Process

The trade imbalances result in some regions possessing a surplus of containers, while others experience deficits, underscoring the necessity for efficient management of empty containers (Braekers et al., 2011). Managing empty containers requires strategic relocation to align with demand while minimizing costs (Braekers et al., 2011). Therefore, carriers are required to strategically reposition empty containers to align with anticipated demand (Braekers et al., 2011). This entails dual levels of repositioning on a global scale to address trade imbalances among major seaports, as well as regionally, concerning the transfer of empty containers among importers, exporters, inland depots, and ports within a defined geographical region (Theofanis & Boilé, 2008).

Generally, empty container planning consists of three stages: strategic, tactical, and operational planning in regional and global contexts (Braekers et al., 2011).

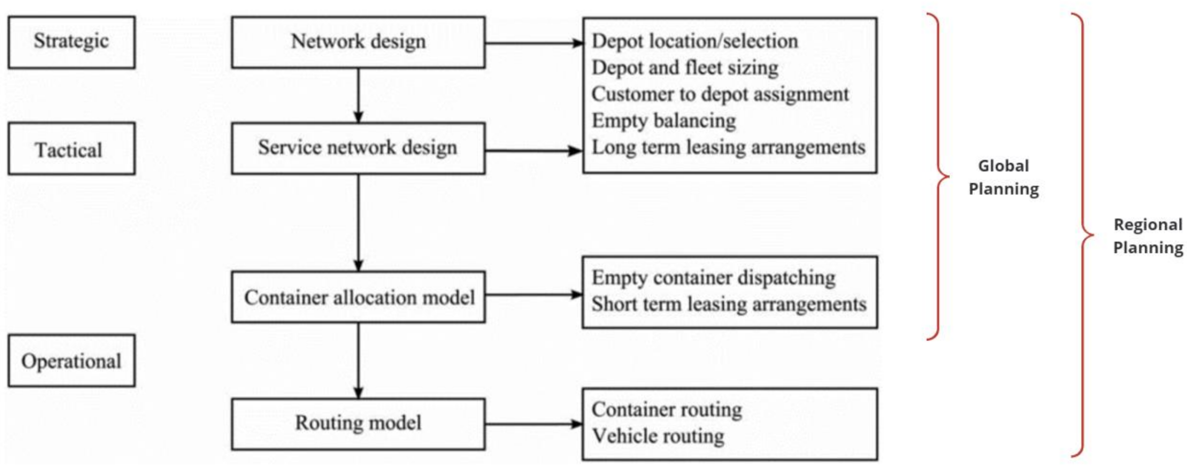


Figure 15 Overview of Decisions for Empty Container Repositioning (Braekers et al. 2011)

4.1 Empty Container Repositioning

4.1.1 Definition

Empty container repositioning is a long-standing and continuous challenge in containerized maritime trade (Boile et al., 2008). Although costly, non-revenue-generating, and generally undesirable, this process is essential for maintaining an effective global transportation system that balances the supply and demand of empty containers between significant exporting and importing regions. Repositioning occurs on three primary levels: global, interregional, and regional, as shown in **Figure 16**.

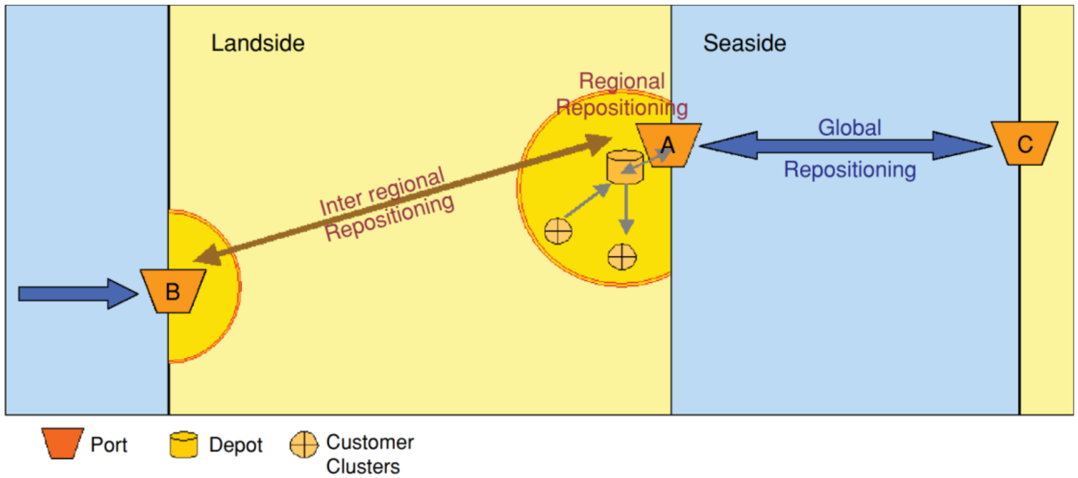


Figure 16 Empty Container Repositioning at Three Levels (Boile et al., 2008)

Globally, empty containers are moved by sea between foreign ports, typically from regions with a surplus of containers to areas experiencing a deficit. For instance, containers filled with goods are shipped from the East (South and Southeast Asia) to the West (North America and Western Europe), with empty containers being repositioned back. **Figure 17** illustrates this global container flow.

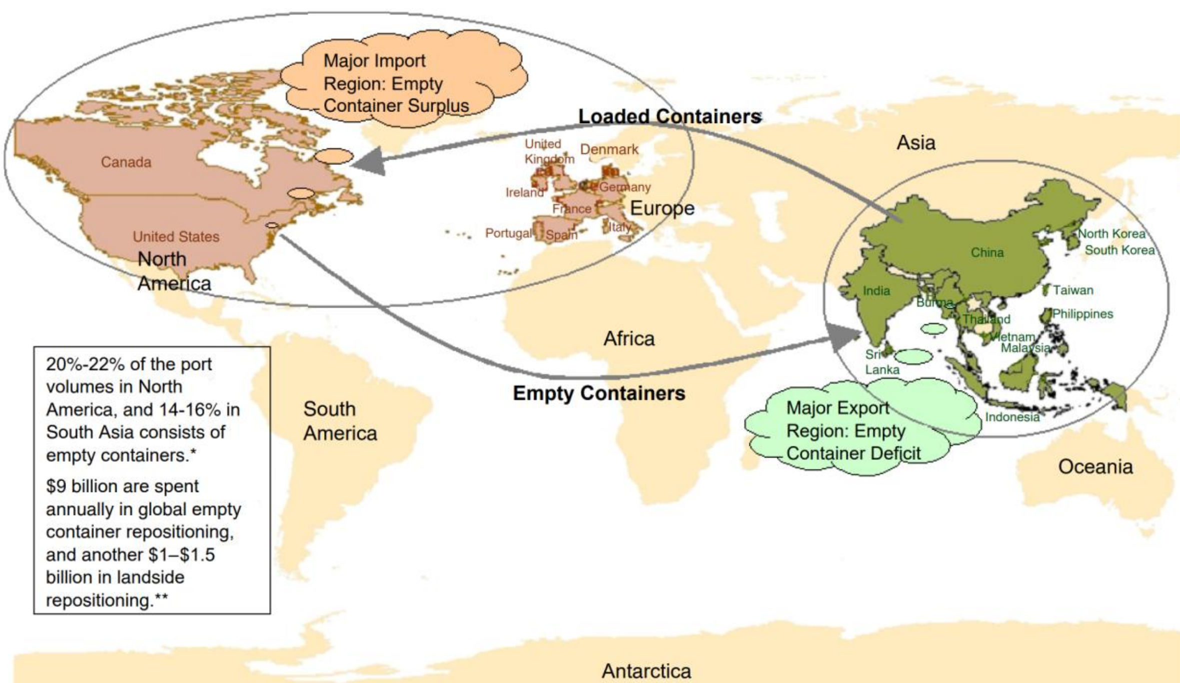


Figure 17 Common Approach in Global Empty Repositioning (Prozzi et al., 2003; Dyna Liners Trades Review, 2006)

At the interregional level, empty containers are transported overland, often by truck or rail, from an import region to a consumption area. Regionally, empty equipment is transferred among importers, exporters, storage facilities, and marine terminals, with trucks being the primary mode of transport. The costs associated with drayage and short-haul rail make rail a less efficient option for regional container repositioning. **Figure 18** outlines current practices in regional container movement.

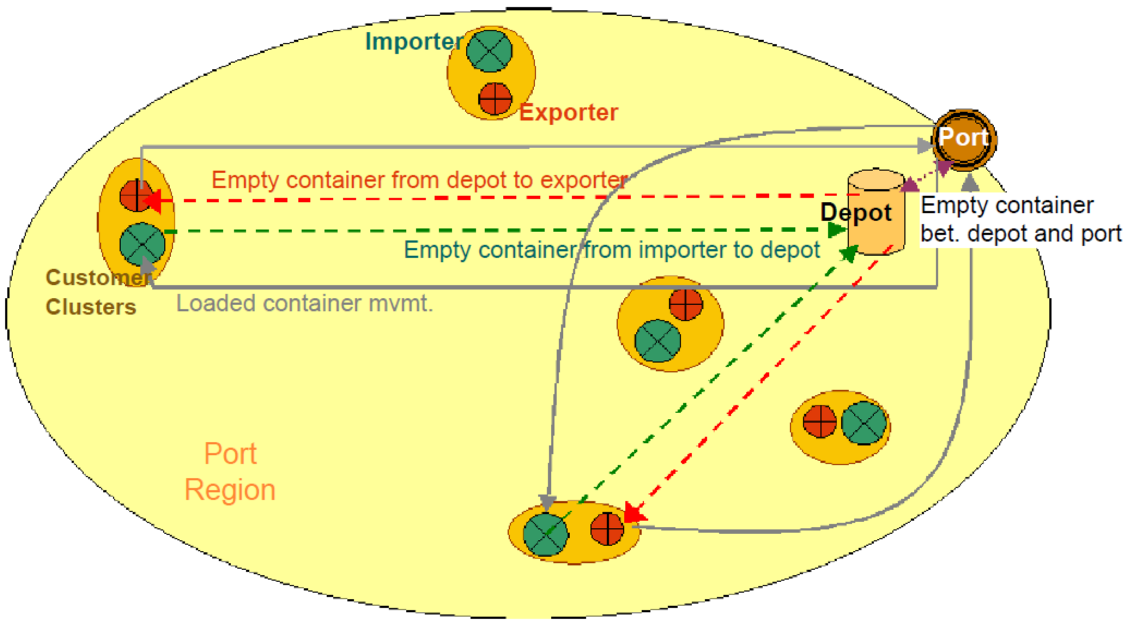


Figure 18 Current Practice in Regional Container Movement (Boile et al., 2008)

4.1.2 Key Factors Associated with Empty Repositioning in the Global Shipping Industry

Trade imbalance contributes to the movement of empty containers. In addition, other factors that may affect the empty container movement include dynamic behavior, uncertainty in demand/handling/transportation, equipment types, blind spots in the transport chain, and a carrier's operational and strategic strategies (Song & Carter, 2009).

a. Dynamic behavior

The constantly changing nature of container fleet handling has long been acknowledged, as it is inherently dynamic in time and location when handling empty equipment. The location of equipment varies in each period, as do the demands, which shift for various reasons, including seasonal products. Even while demand fluctuations were somewhat predictable, they had a fluid influence on the system. The need for empty equipment and the arrival of full equipment for reuse may not align because of timing, location, and volume differences. Empty equipment must be stockpiled in advance to accommodate predicted surges in demand or stored and repositioned as need decreases.

b. Uncertainty in demand/handling/transportation

Uncertainty includes the system's unpredictable variables, such as customer needs and container operations. For example, worker strikes at a port could push cargo ships to alter their schedules, while adverse climate conditions and congestion might delay transportation times. Uncertainty may result in full containers being delivered delayed to customers or empty containers needing to be moved to meet demand. Most container movements diverge from the plan, resulting in additional movements and costs. The increasing uncertainty in shipping demand, driven by market competitiveness, has given shippers more flexibility and higher demands. To address this, shipping lines must allocate spare capacity and optimize the repositioning of empty containers. Unpredictable trade demands on balanced trade routes necessitate empty repositioning to minimize costs.

c. Container types

There are various boxes with distinction in measure and cargo capacity; for instance, some containers are designed to deliver construction goods, automobiles, lumber, cold-chain meals, grain-based goods, powdered items, and liquid substances. The height of twenty-feet unit (TEU) and forty-feet unit containers also varies. Even ports that are close by geographically may handle considerably different sizes of 20- and 40-foot containers. For instance, Yantian, China's global export-driven firm, uses a large percentage of 40-foot containers. It has been noticed that even in cases when trade imbalances are not as substantial, there may still be a considerable demand for empty container movement. A single explanation is that most cargo requires or prefers to utilize specific types of containers.

d. Transport chain's blind spots

The inability to track containers due to the undetected issue in the transportation line can halt shippers from optimizing utilization. Effective fleet management is not feasible without real-time, accurate data about the position and condition of containers.

e. Carrier's operational and strategic strategies

Carriers' behavior patterns are closely correlated with the physical movements of empty equipment. Some carriers, for instance, return empty containers to ports immediately for fast redeployment to Asia, whereas some retain them for as many as thirty days, awaiting export matches before sending them empty. Beyond their internal practices, carriers' external strategies (e.g., forming alliances and sharing vessel slots) influence their empty container logistics. These partnerships often encourage container sharing or exchanges, increasing efficiency and lowering empty repositioning rates.

All these variables originated from a trade imbalance. Carrier operational and strategic strategies impact the actual movements of empty containers; nevertheless, they also represent potential instruments that carriers may utilize to address the empty container repositioning problem.

After discussing the leading causes affecting empty container movement, Dejax and Crainic (1987) discuss the prevalent difficulty occurring in empty container movement as follows:

a) **Type of flow**: focuses solely on empty vehicle flow or includes both empty and loaded vehicle movements simultaneously or sequentially.
b) **Transportation mode**: enables either a single mode of transportation (e.g., train, truck, navigation, container) or multiple types (multimode issues).
c) **Fleet homogeneity**: the problem may affect a single fleet or multiple types of vehicles that must be controlled simultaneously (multicommodity concerns). When vehicle substitution is not permitted in a non-homogeneous fleet problem, the scenario typically breaks down into many homogeneous fleet subproblems.
d) **Type of company**: distinguishing between freight carriers and industrial firms that use rented or owned vehicles for interplant or intra-plant transportation, product distribution, or supply provision.

4.2 Strategic Planning

Strategic planning entails long-term decisions, such as major capital investments. This decision-making level includes constructing the physical network by deciding where to locate inland depots and other facilities, sizing depots and fleets, obtaining resources, designating customer zones, and establishing general service policies. The decision-making process at the strategic level must consider the overall network design, which includes the routes for both laden and empty containers. For instance, it emphasizes that the empty container repositioning problem should be integrated into the entire network design process, influencing route selection and fleet composition (Takano & Arai, 2011). Similarly, it is essential to consider both empty container repositioning and inventory management holistically to minimize costs (Wang et al., 2023).

4.3 Tactical Planning

Tactical planning strives to ensure the efficient and reasonable use of current resources over a medium time horizon, with most decisions at this level focusing on the problem of service network design. Decisions at the tactical level typically comprise the following aspects:

a) Service selection and frequency of services
b) Traffic distribution: specifying routes for each origin-destination pair, including services, terminals, and operations;
c) Terminal policies: consolidating activities at each terminal;
d) Empty balancing strategies: determining how empty vehicles, trailers, and containers should be handled;
e) Vehicle and crew planning: In Europe, vehicles and drivers are treated as a single resource for less-than-truckload transportation, and vehicle trips must consider legal and social criteria.

In addition, customer zones must be assigned to depots based on container type and direction of movement. Empty container balancing flows across depots should be displayed in the same manner as an indication of the volume of the balancing flows required in future periods. Lastly, containers might be imported into the system through long-term leasing agreements to prevent empty container shortages.

4.4 Operational Planning

The **operational planning** level is distinguished by a rapidly changing environment in which service scheduling, resource routing, and dispatching, such as containers, trucks, and staff, are the primary concerns. Operational planning also involves resource allocation and the execution of short-term lease contracts. At the operational level, optimizing regional empty container repositioning requires ensuring that demand for empty containers is met everywhere while also selecting the most efficient routes and transport modalities.

The container allocation model explores the optimal distribution of empty containers while meeting both current and predicted demand. The vehicle routing concept aims to reduce transportation costs for both full and empty containers. It generates a list of travel directions that detail the full and empty motions to be performed over the coming time frame (Crainic et al., 1993).

Unlike regional repositioning, operational priorities for global repositioning of empty containers typically do not require routing decisions. Empty equipment is moved by utilizing empty spaces on vessels transporting laden equipment. As a result, the available capacities for moving empty equipment are included as limitations to each connection in the container allocation model.

At the operational level, empty container repositioning is closely connected to laden container routing. Empty container relocation focuses on optimizing the movement of empty containers within the shipping network to allocate resources better. In contrast, laden container routing involves determining the physical paths of loaded containers to meet customer demands. The movement of laden containers largely influences the movement of empty containers.

At the tactical or strategic level, customer demands, and container flows (both laden and empty) are averaged over medium or long periods, ignoring daily fluctuations. Thus, while vessel capacity may appear sufficient at a strategic level, it may not meet operational needs due to day-to-day variations (Song & Dong, 2012).

4.5 Sub-Conclusion

Empty container repositioning can be categorized into three distinct levels: global, interregional, and regional. ***Global repositioning*** involves the movement of empty containers by sea between international ports, transferring containers from regions with a surplus to those facing a deficit. ***Interregional repositioning*** refers to the transportation of empty containers overland, typically via trucks or rail, from import regions to consumption areas. ***Regional repositioning***, on the other hand, pertains to the transfer of empty containers among importers, exporters, storage facilities, and marine terminals, with trucks serving as the predominant mode of transport.

Several factors are associated with empty container repositioning in the global shipping industry, including 1) Dynamic behavior, 2) Uncertainty in demand/handling/transportation, 3) Container types, 4) Transport chain's blind spot, and 5) Carrier's operational and strategic strategies.

In addition to these factors, it is essential to understand the planning and allocation of empty containers and associated resources across different planning stages: strategic, tactical, and operational. ***Strategic planning*** focuses on long-term decision-making, such as significant capital investments. This includes designing the physical network by determining the locations of inland depots and facilities, sizing depots and fleets, acquiring resources, defining customer zones, and setting overarching service policies. ***Tactical planning*** aims to optimize the utilization of existing resources within a medium-term timeframe, with decisions often centered on service network design. ***Operational planning***, characterized by a dynamic and rapidly changing environment, primarily involves tasks such as scheduling services, routing resources, and dispatching containers, trucks, and personnel.

5. Case Study of Maersk- Comparative Model Construction and Analysis

The methodology that will be conducted in this study case in Maersk will follow the framework explained in **Figure 7**. The **conceptual design** phase already performed in **Chapter 3** and **Chapter 4** to identify relevant parameters to revenue implications. Chapter 5 will mainly focus on the **second phase** of "**Data Collection and Variable Identification**" and some part of **phase 3** of "**Model Design**". The first step to perform in the second phase is the identification of deficit and surplus region.

Figure **19** represents the approach employed to identify the deficit and surplus regions. The findings will be further discussed in Sub-Chapter **5.1 Current State of the Global Trade Balance**. The next step in the second phase is the process of generating alternatives and scenarios which are further discussed in Sub-Chapter **5.2 Alternatives and Scenarios Generation**. The process to define the assumptions and parameters, followed by the identification of independent and dependent variables from the parameter will be elaborated in Sub-Chapter **5.3 Parameters for Model Design** and Sub-Chapter 5.4 **Model Design and Development**. Lastly, the start of phase 3 of **Model Design** will be performed in Sub-Chapter 5.4 **Model Design and Development**.

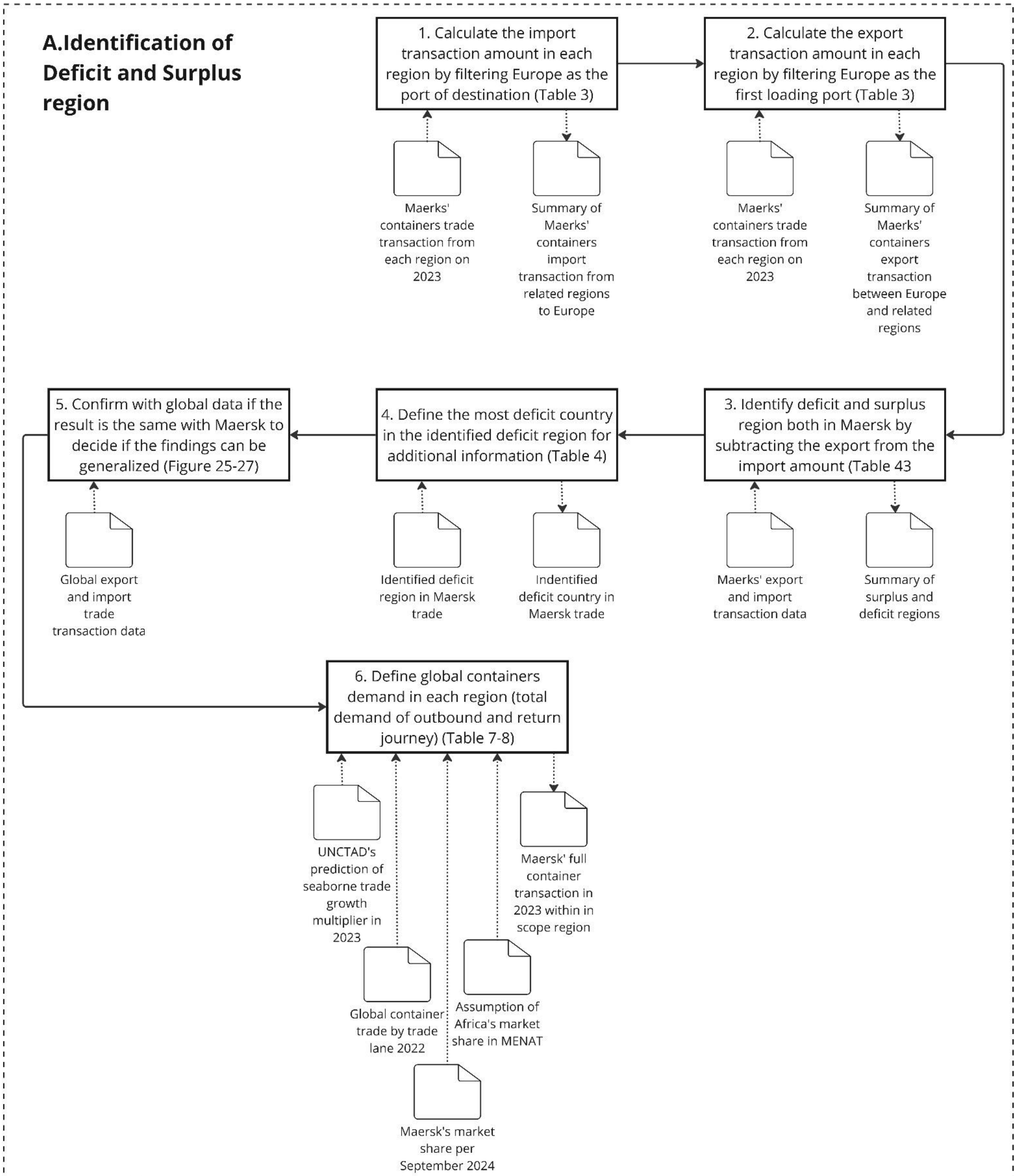


Figure 19 Approach to Determine Global and Maersk Container Trade Balance

5.1 Current State of the Global Trade Balance

The year 2023 can be considered the most representative year for the shipping market, as sales trends have returned to a more stable and normalized state, resembling pre-pandemic conditions. After the unprecedented disruptions caused by the COVID-19 pandemic, which saw a sharp decline in maritime trade in 2020 and an exceptional rebound in 2021, the 2023 performance marks a significant stabilization. Key indicators, such as the normalization of container freight rates, which fell back to pre-pandemic levels after peaking in 2021 due to supply chain disruptions and heightened consumer demand, underscore this return to equilibrium (UNCTAD, 2023).

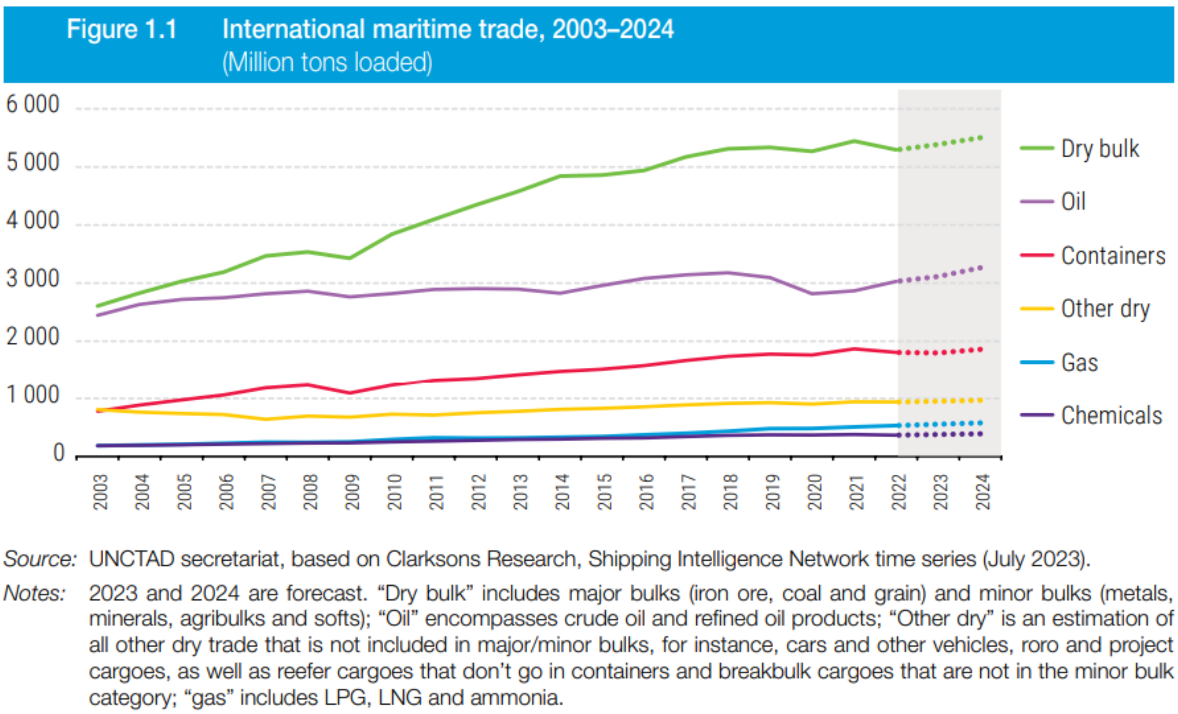


Figure 20 International Maritime Trade in 2003 – 2024 (UNCTAD, 2023)

Additionally, easing port congestion and logistical bottlenecks and resolving labor-related challenges have contributed to a smoother functioning of global trade networks (UNCTAD, 2022). Although global macroeconomic factors, including inflation and geopolitical tensions, continue to influence trade flows, the modest growth in bulk shipments and improved demand for dry bulk commodities further highlight the market's steady recovery (UNCTAD, 2023). Thus, 2023 serves as a pivotal year that reflects the rebalancing of the maritime industry, offering a clearer perspective on trade patterns and market dynamics that are more aligned with pre-pandemic norms.

5.1.1 Regions Experiencing Trade Deficits

As the analysis will focus on the European shipping market, based on the data analyzed from Maersk (**Table 4**), the highest deficit countries between trade from and to Europe during 2023 were the Asia Pacific and Far East areas. The table explains the total FFE (forty-foot equipment) that arrived at the origin and destination.

Table 4 Containers Movement from and to Europe

Country (FLP and POD)	Import	Export	Export - Import	Surplus/Deficit?
Africa	246,200.50	68,208.50	(177,992.00)	Surplus
Asia Pacific	188,369.00	207,795.50	19,426.50	Deficit
Far East	342,723.00	1,180,267.00	837,544.00	Deficit
Latin America	196,436.00	109,604.50	(86,831.50)	Surplus
North America	256,454.00	157,614.50	(98,839.50)	Surplus
West & Central Asia	464,105.00	329,909.00	(134,196.00)	Surplus

As identified in the trade between the Far East and Europe region, China has the highest deficit (**Table 5**).

Table 5 Containers Movement between Far East from and to Europe

Country (FLP and POD)	Import	Export	Export - Import	Surplus/Deficit?
China	238,590.0	1,057,202.5	818,612.5	Deficit
Korea, South	38,294.0	79,888.5	41,594.5	Deficit
Vietnam	30,198.0	68,407.0	38,209.0	Deficit
Cambodia	1,670.5	19,441.5	17,771.0	Deficit
Myanmar (Burma)	824.5	18,274.0	17,449.5	Deficit
Thailand	25,467.0	33,035.0	7,568.0	Deficit
Malaysia	17,171.5	20,782.5	3,611.0	Deficit
Papua New Guine	188.5	616.5	428.0	Deficit
French Polynesia	1.5	-	(1.5)	Surplus
Laos	2.5	-	(2.5)	Surplus
Solomon Islands	2.5	-	(2.5)	Surplus
Brunei	3.5	0.5	(3.0)	Surplus
American Samoa	3.0	-	(3.0)	Surplus
Timor Leste	8.5	2.5	(6.0)	Surplus
Samoa	7.5	-	(7.5)	Surplus
Mongolia	13.5	-	(13.5)	Surplus
Fiji Islands	177.5	11.0	(166.5)	Surplus
Hong Kong China	5,439.5	2,709.0	(2,730.5)	Surplus
New Zealand	11,977.5	8,127.5	(3,850.0)	Surplus
Taiwan China	15,672.5	10,627.5	(5,045.0)	Surplus
Singapore	9,814.5	3,738.5	(6,076.0)	Surplus
Philippines	17,219.5	4,691.5	(12,528.0)	Surplus
Indonesia	41,848.5	28,372.5	(13,476.0)	Surplus
Japan	44,713.5	29,843.5	(14,870.0)	Surplus
Australia	31,782.5	2,295.0	(29,487.5)	Surplus

The results derived from Maersk data are further supported by global statistics, which indicate that China (**Table 5**), the world's largest exporting country (**Figure 21**), has the most significant trade deficit when considering the balance between exports and imports

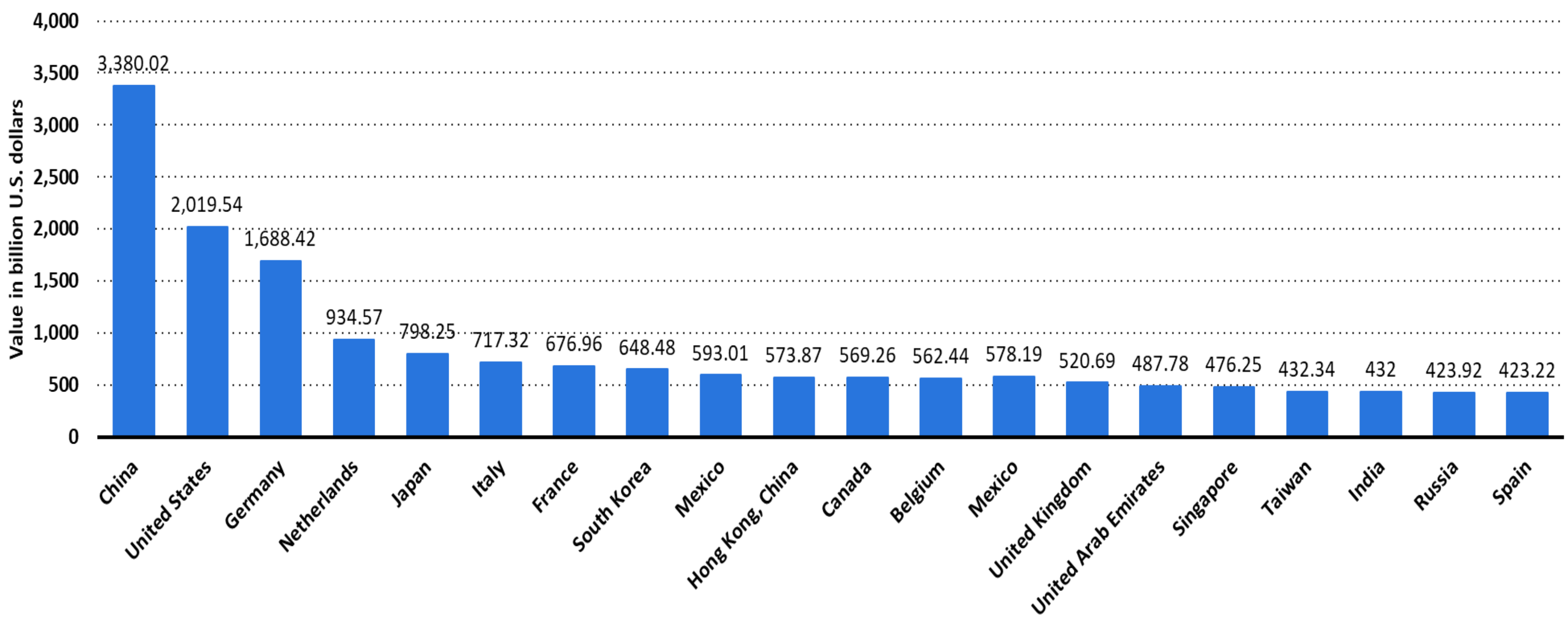


Figure 21 Leading Export Countries Worldwide in 2023 (in billion U.S. dollars) (WTO, 2024)

5.1.2 Regions Experiencing Trade Surplus Globally

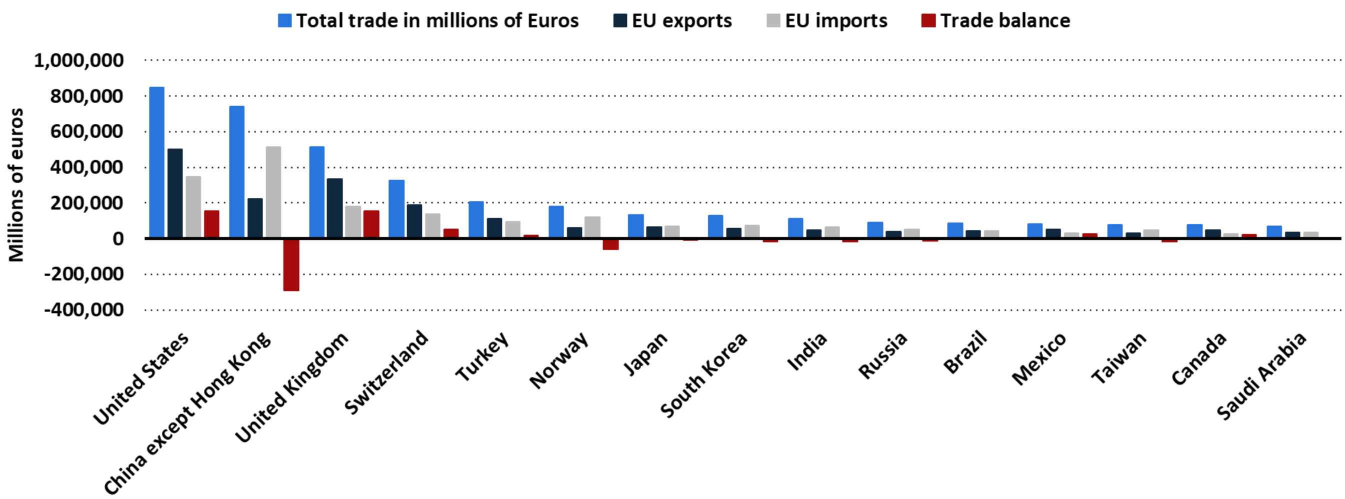


Figure 22 Total Value of the European Union's Trade, Exports, Imports, and Trade Balance In Goods with its Largest Non-EU Trading Partners in 2023 by Country (Statista, 2024a)

Figure 22 illustrates that The United States represents the largest trading partner, with a substantial trade surplus for the EU, which is also supported by the graph in **Figure 23**, which explains the United States as the leading import country. In contrast, China, the second largest partner, shows a significant trade deficit for the EU, indicating higher imports than exports, as supported by data (**Figure 22**). In addition, the EU maintains a trade surplus with Brazil and Canada, exporting more than it imports, while trade with Mexico is nearly balanced.

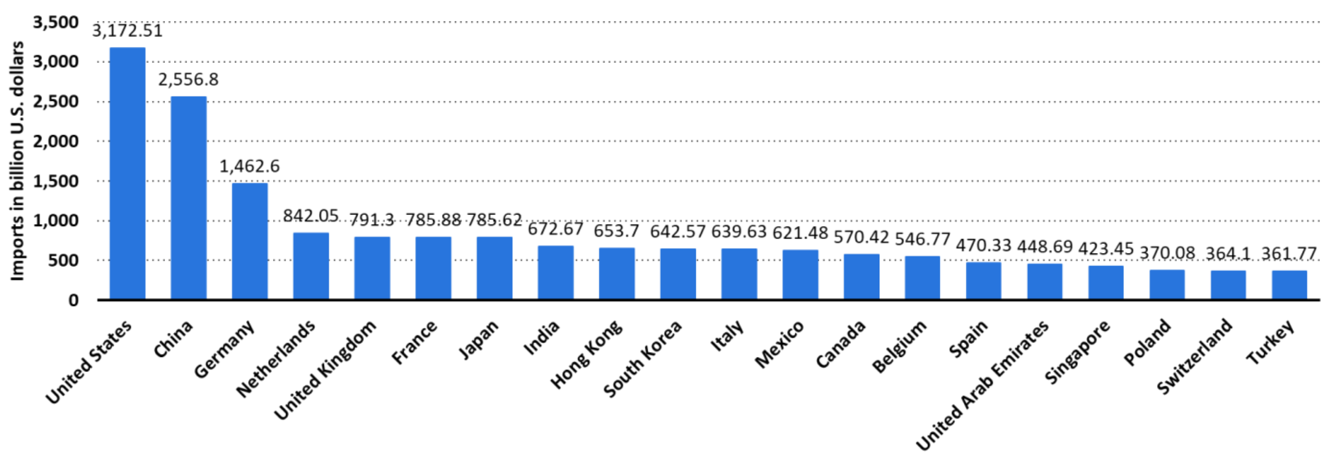


Figure 23 Leading Import Countries Worldwide in 2023 (in Billion U.S. dollars) (WTO, 2024)

5.1.3 Commodity Trade within Europe and its Trade Partners

Figure 24 presents the export/import ratio for various goods traded between the European Union (EU) and the rest of the world in 2023, with the import value normalized to 1. A ratio above 1 indicates that the EU exports more than it import in a particular product category. In contrast, a ratio below one shows that the EU imports more than it export.

In 2023, the EU had the highest export/import ratio for commodities not classified elsewhere, with a ratio of 1.8, meaning the EU exported nearly twice as much in this category as it imported. Chemicals and related products also had a strong export ratio of 1.6. Categories such as food, drinks, tobacco, machinery, and transport equipment also showed more exports than imports, with ratios of 1.4 and 1.3, respectively.

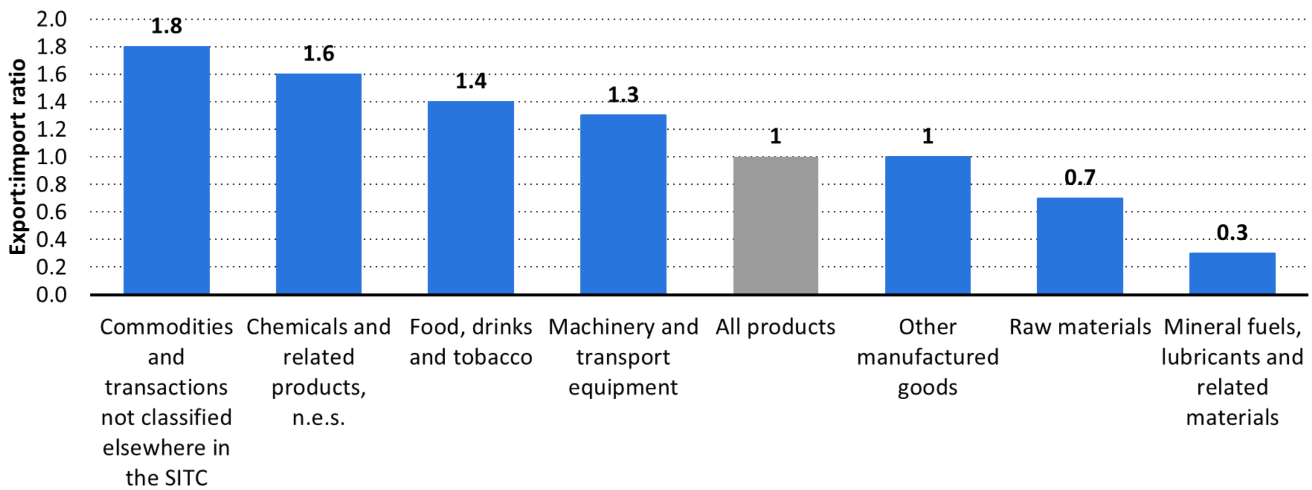


Figure 24 EU Annual Export to Import Ratio by Product Groups 2023 (Statista, 2024a)

In contrast, raw materials had a lower ratio of 0.7, while mineral fuels, lubricants, and related materials were highly import-dependent, with a ratio of only 0.3. The trade balance was even for all combined products and other manufactured goods, with a one-to-one ratio showing equal imports and exports. This indicates that the EU's overall trade balance is more favorable for specific sectors while heavily reliant on imports in others, especially energy-related goods.

Figure 25 illustrates the breakdown of EU trade with China according to SITC (Standard International Trade Classification) categories. The red shades represent primary goods, including food & drink, raw materials, and energy. In contrast, the blue shades indicate manufactured goods, such as chemicals, machinery & vehicles, and other manufactured products. Green is used to denote other goods. **In 2023**, manufactured goods dominated **EU exports to China**, making up 88% of the total, with **primary goods** accounting for **11%**. **Machinery & vehicles** were the most exported manufactured goods (**51%**), followed by **other manufactured goods** (**19%**) and **chemicals** (**18%**). Similarly, **EU imports from China in 2023** were heavily weighted toward manufactured goods (97%) over

primary goods (**3%**), with **machinery & vehicles leading** (**57%**), followed by **other manufactured goods** (**31%**) and **chemicals** (**8%**).

Given the limitations in distinguishing specific cargo types in commodity trade statistics, as outlined previously, and considering the variety of goods transported in multiple ways, the thesis project will focus on overall container throughput measured in TEU (Twenty-foot Equivalent Units) rather than attempting to break down shipments by cargo type. This approach simplifies the analysis and aligns with the variability in how goods such as steel or forest products can be transported in containers or bulk. Prioritizing total TEU offers a more comprehensive overview of port activity without needing to analyze complex commodity classifications.

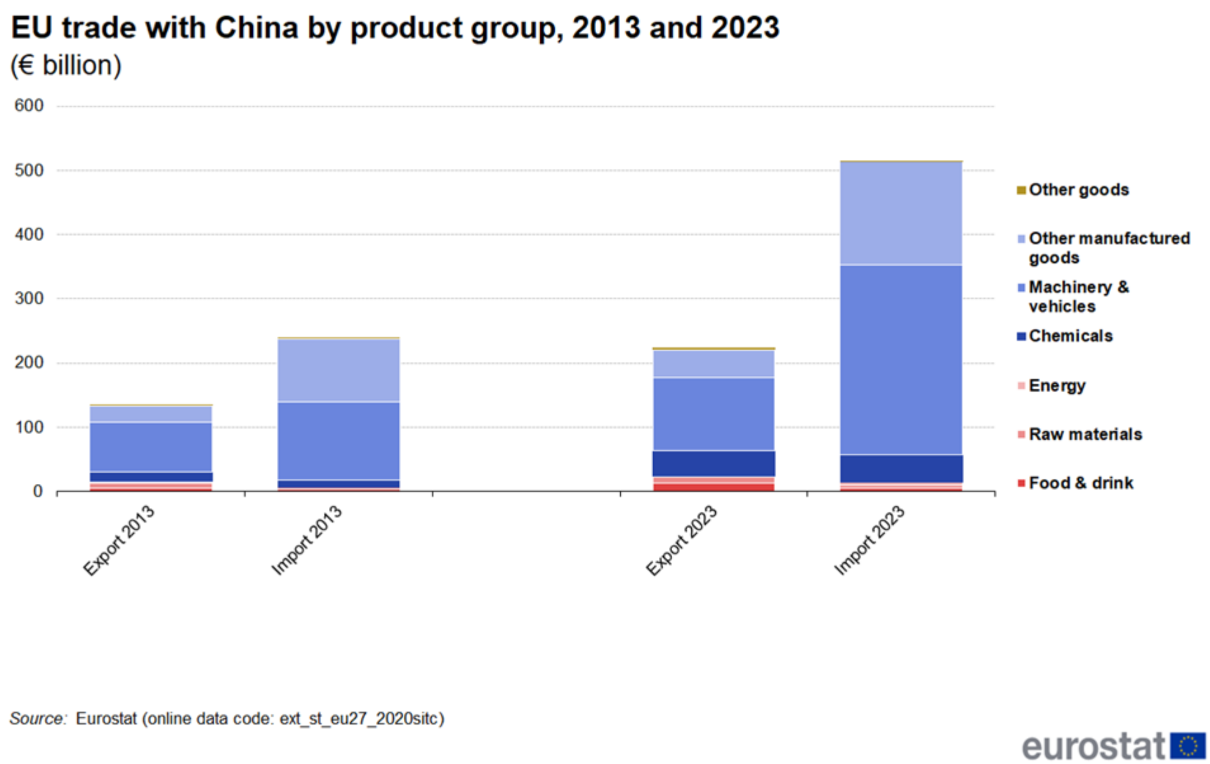


Figure 25 EU Trade with China by Product Group, 2013 and 2023 in Euro Billion (Statistics Explained, 2024a)

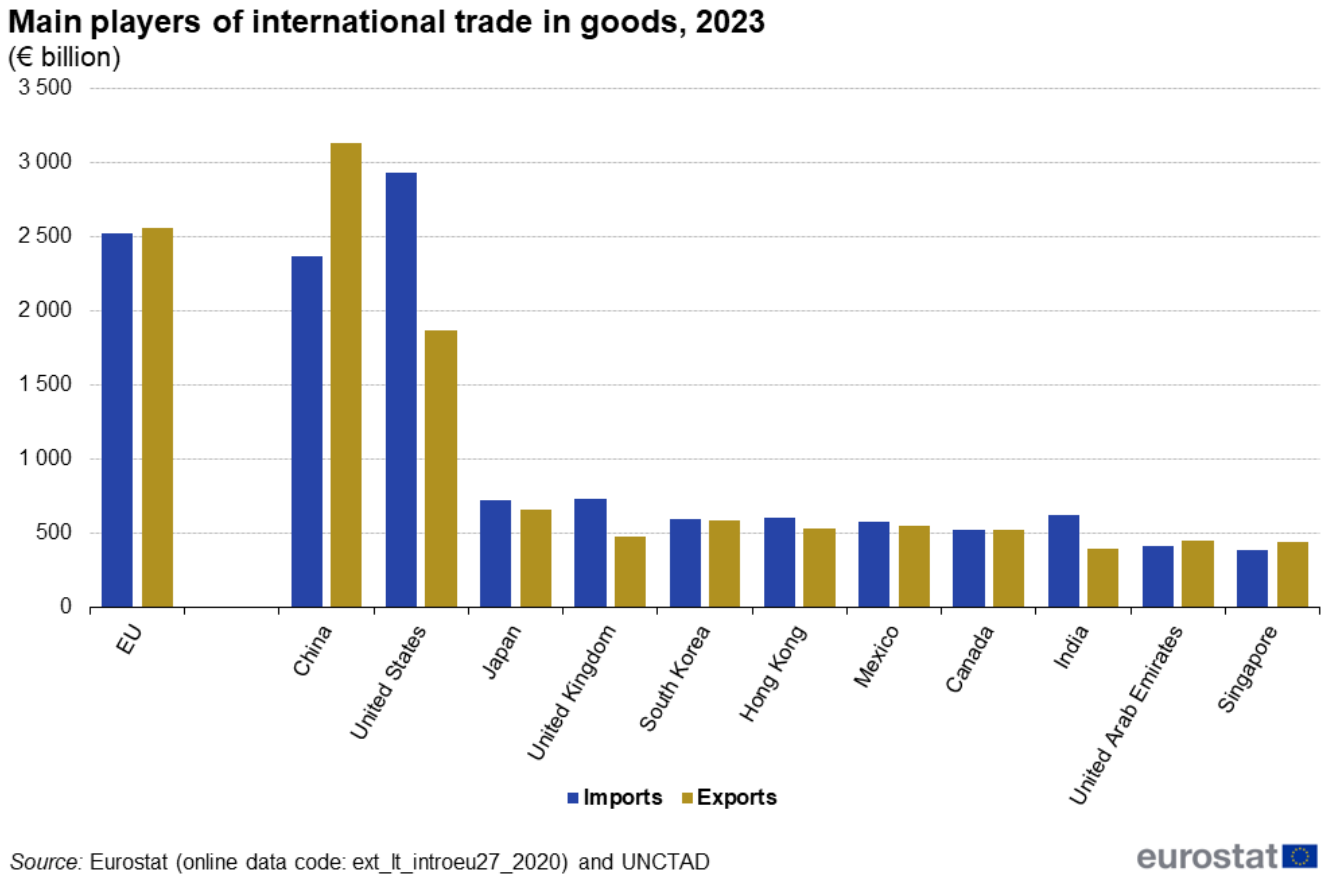


Figure 26 Leading Players of International Trade in Goods, 2023 in Euro Billions (Statistics Explained, 2024b)

The analysis of EU trade in 2023 highlights the varying export/import ratios across different product categories, revealing the EU's strengths in specific sectors like chemicals and machinery while showing dependence on imports in others, particularly energy-related goods. The EU's trade relationship with China also emphasizes its reliance on manufactured goods. Shifting from this sectoral focus to the global trade landscape, the EU, China, and the United States have been the three most prominent global players in international trade (see **Figure 26**), with China surpassing Japan to join this group. In 2023, the EU's total trade in goods (exports and imports) reached €5,073 billion, excluding intra-EU trade, which was €417 billion less than China's trade value and €271 billion higher than that of the United States. Therefore, the analysis focuses on Europe due to the EU's significant role in global trade (Statistics Explained, 2024b).

Since the thesis project will only focus on EU trade, the trade lane considered will only be from and to Europe.

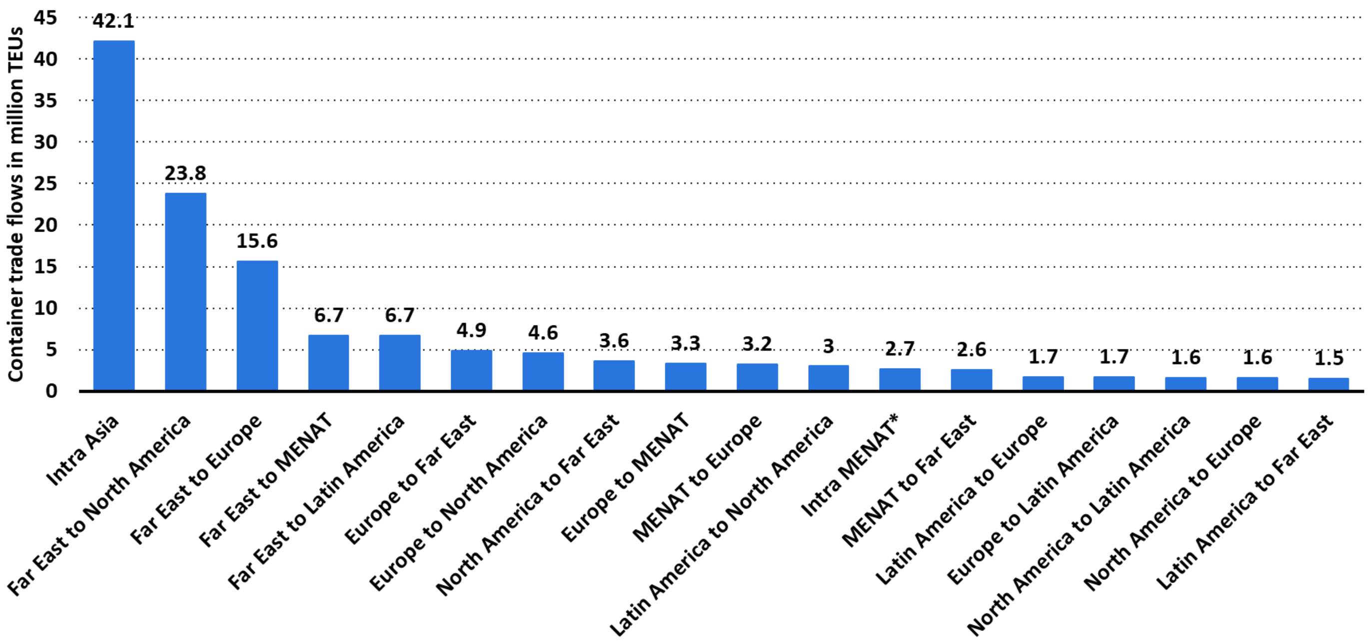


Figure 27 Global Container Trade in 2022, by Trade Lane (in million TEUs) (Statista, 2023)

The European trade lane will follow the general container trade lane provided in Statista (2023), as stated in **Figure 27**. The trade lane in scope will be 1) the Far East, as the highest deficit contributor in EU trade; 2) North America, with the United States as the highest surplus contributor countries in North America; 3) Latin America, since they also contribute as the surplus contributor region (Canada, Brazil, Mexico), and 4) Africa.

In addition, the Red Sea crisis has created significant disruptions for shipping companies, impacting one of the world's major maritime trade routes, responsible for approximately 12% of global trade. Consequently, many shipping lines have rerouted vessels via the longer Cape of Good Hope route, resulting in extended transit times and increased operational costs. This deviation also elevates insurance premiums due to the distinct risks associated with the Cape route, which, in turn, are transferred to consumers through higher prices for goods and services. Africa's strategic importance in this alternative route underscores its potential to contribute to future revenue within global maritime trade dynamics (Guest, 2024).

5.2 Alternatives and Scenarios Generation

As mentioned before, there are two developed general alternatives that will be analyzed to understand the revenue of each strategy below:

1) **Alternative 1**: Maintaining Maersk's business approach as implemented in 2023, which balances fulfilling export demand from all regions while continuing to address export needs from surplus areas.
2) **Alternative 2**: Prioritizing empty container deployment to deficit regions by curtailing the full containers from Europe's outbound journey (Europe to any region, except Far East) and relocating those supposedly laden containers empty from Europe to Far East so that empty containers can be utilized as laden to fulfill demand on Far East to Europe.

Several possibilities exist in allocating additional empties outbound from the EU to various regions (Alternative 2), influencing the total revenue. The defined number of additional empties are allocated outbound from the EU to the Far East and hence, adjustments must be made to other regions.

a. In Scenario 1, the outbound flow to Africa will be curtailed, with no changes to flows to Latin America or North America and no impact on the return flows from these regions, except that the return from the Far East will equal the outbound value from the EU to the Far East, which amounted to the same as the additional emptied.
b. In Scenario 2, the additional empties outbound from the EU to Latin America would be curtailed. At the same time, all other flows remain unchanged, except that the return from the Far East will equal the outbound value from the EU to the Far East, which amounted to the same as the additional empties.
c. In Scenario 3, the additional empties outbound to North America could be curtailed, with other flows remaining unaffected. Except that the return from the Far East will equal the outbound value from the EU to the Far East, which is the same as the additional empties.
d. In Scenario 4, the additional empties could be reduced by combining the reduced empties from three regions: Africa, North America, and Latin America.

Referencing from Sub Chapter 3.3 Shipping Route, **Figure 10**, the study case will use the term return journey to define the inbound journey, while outbound journey still remain the same.

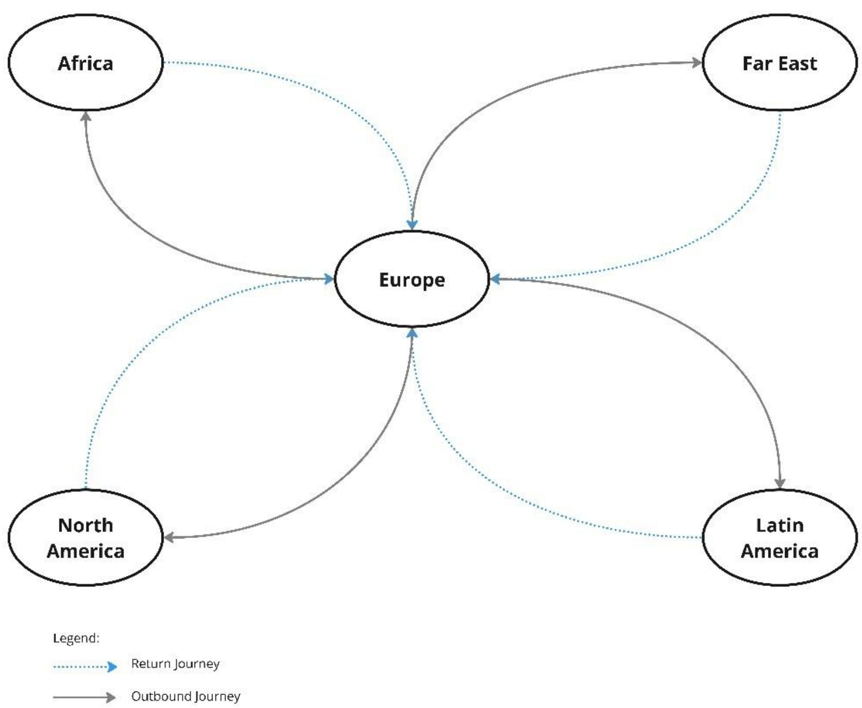


Figure 28 Description of Outbound and Return Journey

In addition to the possible scenarios on how to obtain additional empties container within Far East and Europe trade, Alternative 2 will also analyze the impact of seasonality when performing this alternative. Analysis without seasonality will focus on calculating the full year only. While when seasonality applies, the calculation will first be conducted in monthly basis because there will be trend of demand in each month. The monthly calculation will be totaled into full year, that will then be compared to Alternative 1 and Alternative 2 without seasonality.

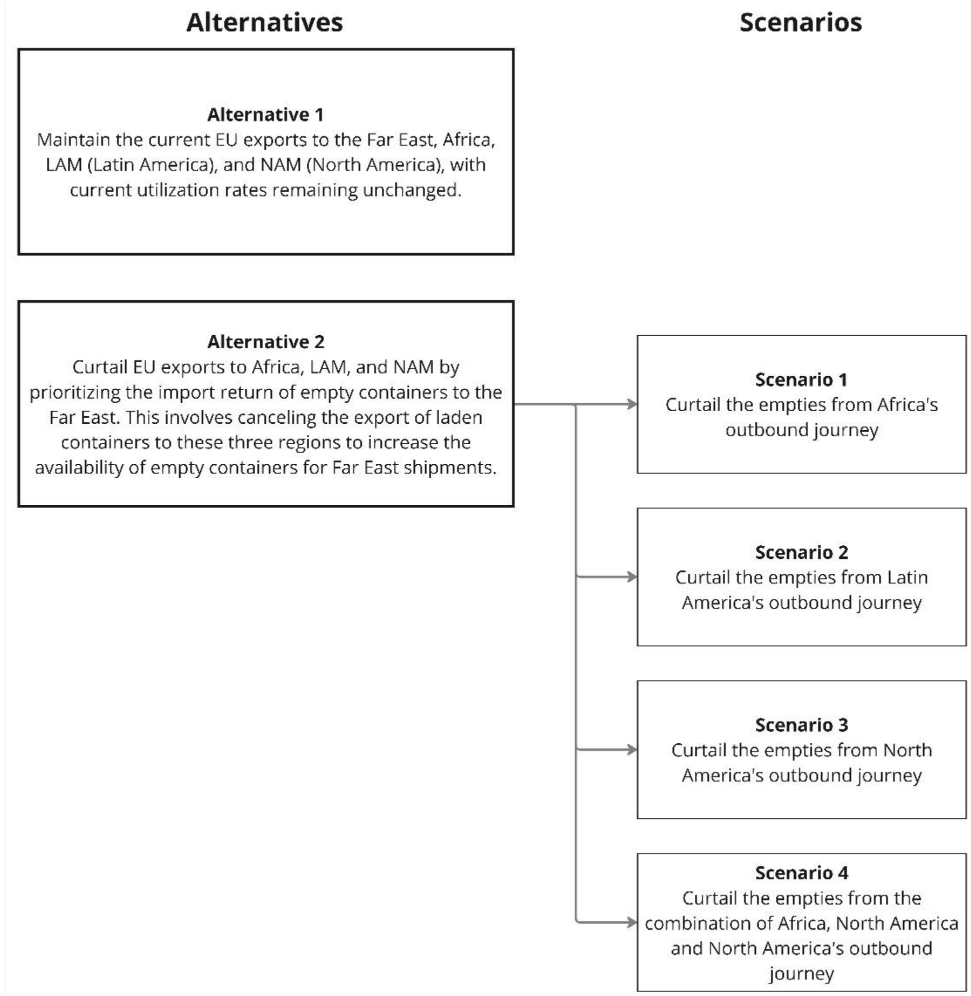


Figure 29 Summary of Defined Alternatives and Scenarios

5.3. Parameters for Model Design

The analysis in chapters 3 and 4 provided a comprehensive understanding of the current context within the shipping market, detailing the complexities of container demand and supply dynamics, decision-making processes at various planning stages in container management, and the critical factors associated with the empty repositioning process. These insights laid the groundwork for constructing a comparative model to evaluate the revenue implications of maintaining current export levels versus prioritizing empty container allocation to deficit regions. Based on the theoretical background and interview with the Equipment Flow team, several parameters will be used for analysis, directly impacting revenue.

Sub-Chapter 3.4 highlighted the dynamics of supply and demand interactions, emphasizing how freight rates respond to market fluctuations and economic conditions, further influenced by psychological market factors.

Sub-Chapters 4.2, 4.3, and 4.4 underscored the strategic, tactical, and operational planning essential for managing empty containers, emphasizing repositioning between surplus and deficit regions. They also highlighted optimal resource capacity utilization as key to operational effectiveness.

Sub-Chapter 4.1.2 (Section "Uncertainty in demand/handling/transportation") explored key factors affecting empty container repositioning, particularly the impact of trade imbalances that necessitate the strategic allocation of container demand to deficit regions. The analysis underscored the influence of unpredictable elements such as weather and traffic congestion on transit times, noting that these uncertainties can lead to delays in delivering full containers and hinder the timely repositioning of empty ones to meet demand. This chapter emphasized the importance of accounting for these variables in strategic planning to mitigate potential disruptions and optimize revenue. This chapter (Section "Dynamic Behavior") also explains that it is essential to meet the demand in the needed areas by ensuring that the empty equipment is available in the area of demand and sometimes must be stockpiled to accommodate predicted surges in demand or repositioned as need decreases.

Revenue will be measured in terms of Total Revenue. Transit time will impact on the total revenue generated per day. At the same time, it is also essential to measure the opportunity cost or loss of revenue when choosing one alternative over another (Berk & DeMarzo, 2017).

Chapter 5 aligns theoretical insights with practical implications by incorporating multifaceted factors such as freight rates, resource capacity utilization, demand in deficit areas, opportunity costs, and transit time into the model. It provides an in-depth analysis that synthesizes these aspects to offer a comprehensive understanding of how targeted container allocation strategies can enhance revenue within the shipping industry.

Table 6 Parameters for Model Design

Parameters	Reference
Freight rates	Sub-Chapter 3.4
Utilization Rates	Sub-Chapters 4.2, 4.3, and 4.4
Demand in Deficits Areas	Sub-Chapter 4.1.2
Opportunity Cost (Loss of Revenue)	Berk & DeMarzo (2017)
Transit Time	Sub-Chapter 4.1.2
Total Revenue	Berk & DeMarzo (2017)
Total Revenue per Day	Berk & DeMarzo (2017)
Opportunity Cost (Loss of Revenue) per Day	Berk & DeMarzo (2017)

5.4 Model Design and Development

To ensure that the data used in this case study is representative, the normalization techniques will be applied so that it follows the pattern of Maersk's data. Hence, even with generalized data, it will still align with the weekly and monthly container movement trends observed in Maersk's data for all relevant parameters.

The study case applies the assumptions below:

1. The total TEU transported by Maersk to each region in 2023 is calculated based on its 14.3% market share, as reported by Alphaliner data as of September 28, 2024, assuming the number as the total full and empty containers loaded in that year.
2. The growth multiplier for 2023 is 1.2%, as per UNCTAD data.
3. The analysis focuses exclusively on region-to-region trade involving Europe and global repositioning only (which requires seaside transportation).
4. The analysis excludes intermodal transfers and feeder services, considering the focus on direct port-to-port transportation.
5. All types of containers transported on vessels are considered in the analysis (refer to Sub-Chapter 3.4).
6. The utilization rate is based on Maersk's 2023 utilization rate, rounded to the nearest whole number.
7. The freight rate is based on the spot market rate as of October 9, 2024.
8. All containers are assumed to return to their respective trade lanes based on their origin.
9. Only outbound journeys will be impacted by the curtailing process, while demand for return journeys remains unaffected.
10. Revenue loss will only impact outbound shipments (EU to Latin America, North America, and Africa), as these regions have surpluses, meaning return journeys are unaffected.
11. Transit time accounts solely for time spent on water.
12. The total number of full TEU containers is considered fixed.
13. The analysis does not include the cost incurred related to the increase in transit time due to increased waiting time due to port congestion.

As explained in Sub-Chapter 5.3, the key parameters that will be analyzed are freight rates, container utilization, demand in deficit areas, opportunity costs, and transit time. The independent variables in this analysis include freight rates, transit times, and additional empty containers (specific for Scenario 2). **Freight rates** are assumed to follow a uniform distribution with a minimum increase of 20% and a maximum decrease of 30%, as outlined in **Table 7**. The data distribution is defined based on the average fluctuation of contract freight rates from 2018–2021 for 40-feet containers (**Table 10**). The freight rate changes from 2021/2020 are excluded due to the significant fluctuations caused by the pandemic, which are not representative of typical conditions (**Table 10**). **Transit times** are also assumed to follow a uniform distribution, with an increase ranging from 5% to 30%. For Scenario 2, additional empty containers (**demand in deficit areas**) are assumed to be between 3,600 and 35,500 million TEUs.

Table 7 Summary of Parameters Data Distribution and Value

	Freight Rate ($)	Utilization Rates	Demand in Deficits Area (million TEUs)	Opportunity Cost ($)	Transit Time (days)
Far East to Europe	2,202	95%	35,500	Depends on the freight rate of the curtailed region's	48
Europe to Far East	228	96%		Depends on the freight rate of the curtailed region's	54
North America to Europe	799	82%		Depends on the freight rate of the curtailed region's	16
Europe to North America	1,722	90%		Depends on the freight rate of the curtailed region's	17
Latin America to Europe	1,318	78%		Depends on the freight rate of the curtailed region's	22
Europe to Latin America	1,034	81%		Depends on the freight rate of the curtailed region's	27
Africa to Europe	1,943	70%		Depends on the freight rate of the curtailed region's	31
Europe to Africa	1,109	86%			33
Data distribution	**Uniform distribution minimum increase 20% maximum decrease 30%**	-	**ranging between 3600 until 35.500**	-	**uniform distribution increase from 5% to 30%**

The basis of projected demand in 2023 is based on UNCTAD data, which projects that containerized seaborne trade will expand by 1.2 percent in 2023, with moderate growth of around 3 percent annually from 2024 onward as macroeconomic conditions stabilize.

The demand reflects the number of containers in TEUs arriving at the region's origin and destination. These forecasts are based on IMF's July 2023 projections, which predict global GDP growth of 2.9 percent in 2023. The IMF scenario anticipates rising inflation, tighter financial conditions, a greater-than-expected economic slowdown in China, negative impacts from the ongoing war in Ukraine, and persistent supply-demand imbalances hampering growth despite unexpected trade growth in 2022 and 2023 (Sirimanne et al., 2023).

Due to the limited availability of data for 2023, the global container trade data for 2023 will utilize the 1.2 percent growth multiplier projected by UNCTAD. It is assumed that all trade lanes will experience a 1.2 percent growth increase.

Table 8 Estimation of Containers Arrived at the Region's Origin and Destination in 2023 by Trade Lane (in a million TEUs) (Statista, 2023)

Global container trade in 2023 by trade lane (in million TEUs)	2022	2023	Maersk's Share	TEU from-to Africa
Intra-Asia	42.10	42.61	6.09	
Far East to North America	23.80	24.09	3.44	
Far East to Europe	15.60	15.79	**2.26**	
Far East to MENAT	6.70	6.78	0.97	
Far East to Latin America	6.70	6.78	0.97	
Europe to Far East	4.90	4.96	**0.71**	
Europe to North America	4.60	4.66	**0.67**	
North America to Far East	3.60	3.64	0.52	
Europe to MENAT	3.30	3.34	**0.48**	**0.105**
MENAT to Europe	3.20	3.24	**0.46**	**0.102**
Latin America to North America	3	3.04	0.43	
Intra MENAT*	2.70	2.73	0.39	
MENAT to Far East	2.60	2.63	0.38	
Latin America to Europe	1.70	1.72	**0.25**	
Europe to Latin America	1.70	1.72	**0.25**	
North America to Latin America	1.60	1.62	0.23	
North America to Europe	1.60	1.62	**0.23**	
Latin America to Far East	1.50	1.52	0.22	

*Source: Statista (2023)

Table 9 Total Trade in A Full Container Arrived at The Region's Origin and Destination for In-Scope Analysis

In Scope Trade Route	Total Trade of Full TEU (in million TEUs)	Total Trade per Region (in million TEUs)
Far East to Europe	**2.26**	**2.97**
Europe to Far East	**0.71**	
Africa to Europe	**0.102**	**0.207**
Europe to Africa	**0.105**	
Europe to Latin America	**0.25**	**0.5**
Latin America to Europe	**0.25**	
North America to Europe	**0.23**	**0.9**
Europe to North America	**0.67**	

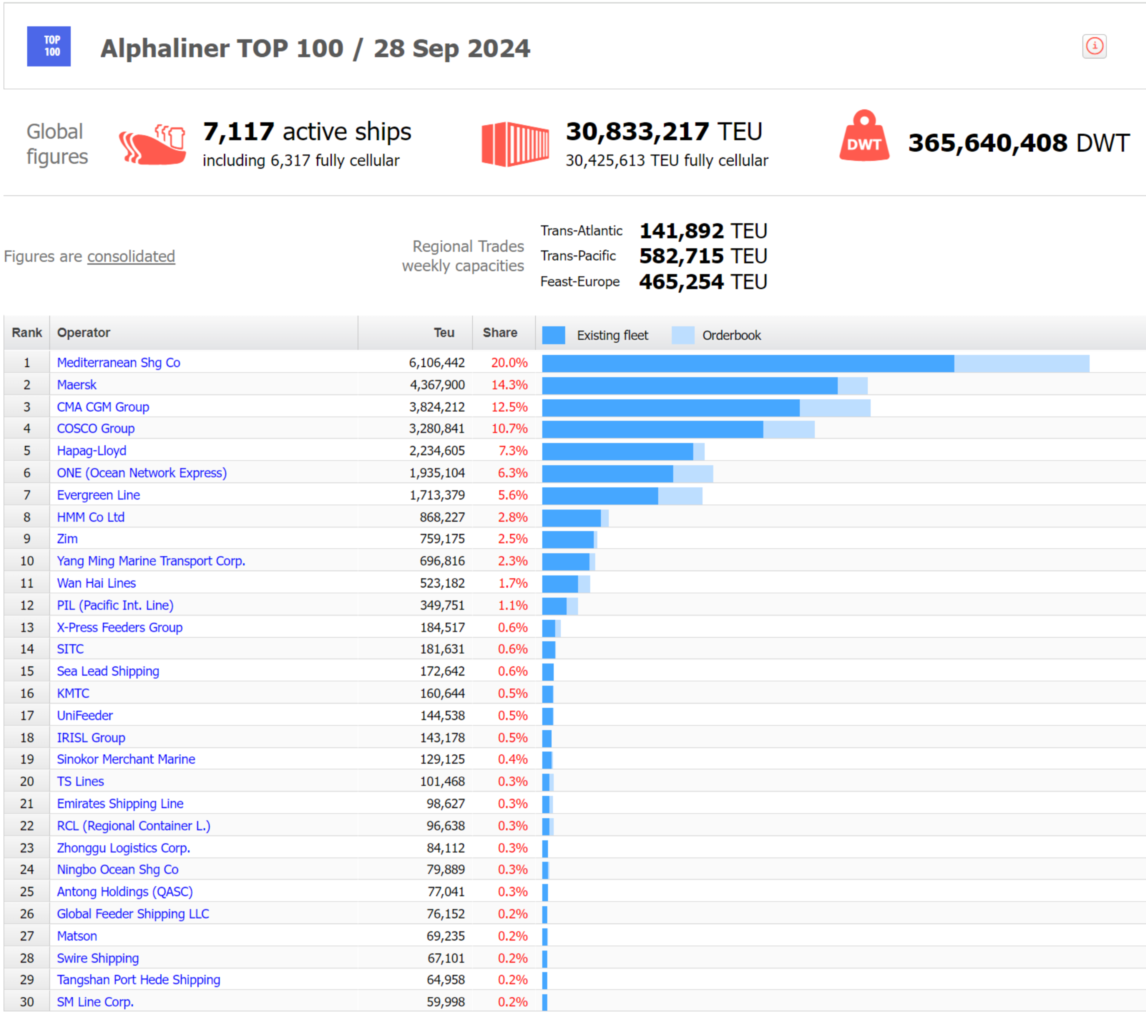
If we look at the data in **Table 9**, trade between Europe and Far East contributes the highest volume among all regions, while trade between Europe and North America placed the second highest volume.

Table 10 Contract Freight Rate (in dollars) in 2018 – 2021 per 40-foot containers (FEU) (UNCTAD, 2022)

From	To	2018	2019	2020	2021	2020/19	2020/18	2021/2020	2021/2018
Africa	Africa	1 812	1 849	1 924	2 013	4.1%	6.2%	4.6%	11.09%
	Asia	748	750	775	664	3.2%	3.6%	-14.3%	-11.19%
	Europe	1 431	1 643	1 747	1 487	6.3%	22.1%	-14.8%	3.96%
	South America	2 010	1 860	1 979	1616	6.4%	-1.5%	-18.3%	-19.59%
Asia	Africa	1 800	1 927	2 112	2 733	9.6%	17.4%	29.4%	51.89%
	Asia	737	747	821	1 194	9.8%	11.4%	45.5%	62.00%
	Europe	1 782	1 847	1 916	3 285	3.8%	7.5%	71.4%	84.39%
	North America	2 426	2 603	2 711	3 820	4.1%	11.8%	40.9%	57.48%
	Oceania	1 770	1 790	1 850	2 800	3.4%	4.6%	51.3%	58.24%
	South America	2 290	2 075	2 230	3 589	7.5%	-2.6%	61.0%	56.74%
Europe	Africa	1 595	1 650	1 858	1 727	12.6%	16.5%	-7.1%	8.23%
	Asia	967	870	1 004	1 225	15.4%	3.8%	22.0%	26.61%
	Europe	804	881	976	1 077	10.7%	21.3%	10.3%	33.84%
	North America	1 518	1 742	2 256	2 304	29.5%	48.7%	2.1%	80%
	Oceania	1 996	1 933	2 077	2 319	7.4%	4.1%	11.7%	16.18%
	South America	1 019	1 302	1 376	1 465	5.6%	35.0%	6.5%	43.79%
North America	Africa	2 890	3 112	2 981	2 639	-4.2%	3.2%	-11.5%	-8.66%
	Asia	1 009	1 111	1 269	1 385	14.2%	25.8%	9.17%	37.29%
	Europe	858	1 109	1 323	1 053	19.3%	54.2%	-20.4%	22.75%
	North America	1 534	1 429	1 584	1 362	10.8%	3.2%	-14.0%	-11.22%
	Oceania	2 538	2 634	2 996	2 475	13.8%	18.1%	-17.4%	-2.47%
	South America	1 254	1 318	1 486	1 064	12.7%	18.5%	-28.4%	-15.15%
South America	Africa	1 778	1 951	2 000	2 187	2.5%	12.5%	9.3%	22.99%
	Asia	1 623	1 963	1 802	1 841	-8.2%	11.0%	2.2%	13.42%
	Europe	1 313	1 977	1 961	1 767	-0.8%	49.3%	-9.9%	34.52%
	North America	1 521	1 882	1 745	1 969	-7.3%	14.7%	12.9%	29.50%
	South America	1 349	1 699	1 539	1 243	-9.4%	14.1%	-19.2%	-7.84%

Assume that Maersk's share in the market is 14.3% as stated in Alphaliner data (**Figure 30**), so based on the total predicted number of TEU in 2023, Maersk's trade globally can be calculated as indicated in column "Maersk's Share" in **Table 8**. As for European trade from and to Africa, the trade can be calculated as a 12% contributor to global trade due to the role of Africa as the alternative route because of the geopolitical issue of the Red Sea (Guest, 2024).

As Africa is part of MENAT, assume that 12% of MENAT trades go to Africa, which results in Maersk's share in Africa, as stated in **Table 8**.



Alphaliner TOP 100 / 28 Sep 2024

Global figures: **7,117** active ships, including 6,317 fully cellular; **30,833,217** TEU, 30,425,613 TEU fully cellular; **365,640,408** DWT

Figures are consolidated

Regional Trades weekly capacities: Trans-Atlantic **141,892** TEU; Trans-Pacific **582,715** TEU; Feast-Europe **465,254** TEU

Rank	Operator	Teu	Share
1	Mediterranean Shg Co	6,106,442	20.0%
2	Maersk	4,367,900	14.3%
3	CMA CGM Group	3,824,212	12.5%
4	COSCO Group	3,280,841	10.7%
5	Hapag-Lloyd	2,234,605	7.3%
6	ONE (Ocean Network Express)	1,935,104	6.3%
7	Evergreen Line	1,713,379	5.6%
8	HMM Co Ltd	868,227	2.8%
9	Zim	759,175	2.5%
10	Yang Ming Marine Transport Corp.	696,816	2.3%
11	Wan Hai Lines	523,182	1.7%
12	PIL (Pacific Int. Line)	349,751	1.1%
13	X-Press Feeders Group	184,517	0.6%
14	SITC	181,631	0.6%
15	Sea Lead Shipping	172,642	0.6%
16	KMTC	160,644	0.5%
17	UniFeeder	144,538	0.5%
18	IRISL Group	143,178	0.5%
19	Sinokor Merchant Marine	129,125	0.4%
20	TS Lines	101,468	0.3%
21	Emirates Shipping Line	98,627	0.3%
22	RCL (Regional Container L.)	96,638	0.3%
23	Zhonggu Logistics Corp.	84,112	0.3%
24	Ningbo Ocean Shg Co	79,889	0.3%
25	Antong Holdings (QASC)	77,041	0.3%
26	Global Feeder Shipping LLC	76,152	0.2%
27	Matson	69,235	0.2%
28	Swire Shipping	67,101	0.2%
29	Tangshan Port Hede Shipping	64,958	0.2%
30	SM Line Corp.	59,998	0.2%

Figure 30 Maersk's Global Share Percentage as of 28 September 2024

Finally, the study case will use the data in

Table **11** to be run in the simulation using Monte Carlo simulation. In the case of seasonality analysis in Alternative 2, the data use will be different because there will be variation in the data in each month due to the seasonality. Seasonality analysis in Alternative 2 will employ the data in **Appendix B** for the monthly data. The data distribution for freight rate (**Appendix C**) and additional empties for repositioning (**Appendix D**) will also differ due to the seasonality. Ultimately, the monthly result in Alternative 2 with seasonality will be aggregated as the full year result. The aggregated full year result will be compared to the full year result in Alternative 1 and 2 without seasonality. The seasonality testing will only be performed on the Total Revenue since the objective is to find out the impact of seasonality in the revenue generation when prioritizing the empty containers allocation to deficit area.

Table 11 Full Year Data Employed in Simulation

Region	Total Full TEU (million)	Total Empty TEU (million)	Freight Rate per TEU (dollars)	Average Transit Days	Operational Allowance (TEU)
EU to Far East	710,000	132,826.00	228	54	882,725
Far East to EU	2,260,000	10,001.00	2,202	48	2,397,045
EU to Africa	105,000	10,101.00	1,943	31	133,527
Africa to EU	102,000	9,883.00	1,109	33	160,107
EU to Latin America	250,000	9,116.00	1,034	27	322,043
Latin America to EU	250,000	9,106	1,318	22	331,550
EU to North America	670,000	10,027	1,722	17	757,353
North America to EU	230,000	10,086	799	16	292,147

5.4.1 Freight Rates

Freight shipping rates refer to the costs incurred by the customer to the shipper for transporting goods through various modes such as ocean, air, rail, or road. These rates are influenced by transport method, distance, cargo volume, weight, dimensions, market conditions, and seasonal variations, collectively determining the overall cost of freight shipping. In ocean freight, several critical components contribute to the total cost (Freightos, 2024):

a) Base Freight Rate refers to the primary cost of shipping goods from the departure to the destination port.
b) Bunker Adjustment Factor (BAF) refers to a surcharge to account for changes in fuel prices.
c) Currency Adjustment Factor (CAF) refers to a fee that offsets fluctuations in exchange rates.
d) Terminal Handling Charges (THC) refer to fees levied by port authorities for container handling at both origin and destination.
e) Surcharges refer to additional charges that may apply for specific circumstances, such as handling hazardous materials, peak season demands, or port congestion.

The freight rate assumed in this thesis project will be the spot market base rate as of 9 October 2024 for the chosen port in each region's scope. The process of defining the freight rate is summarized in **Figure 31**.

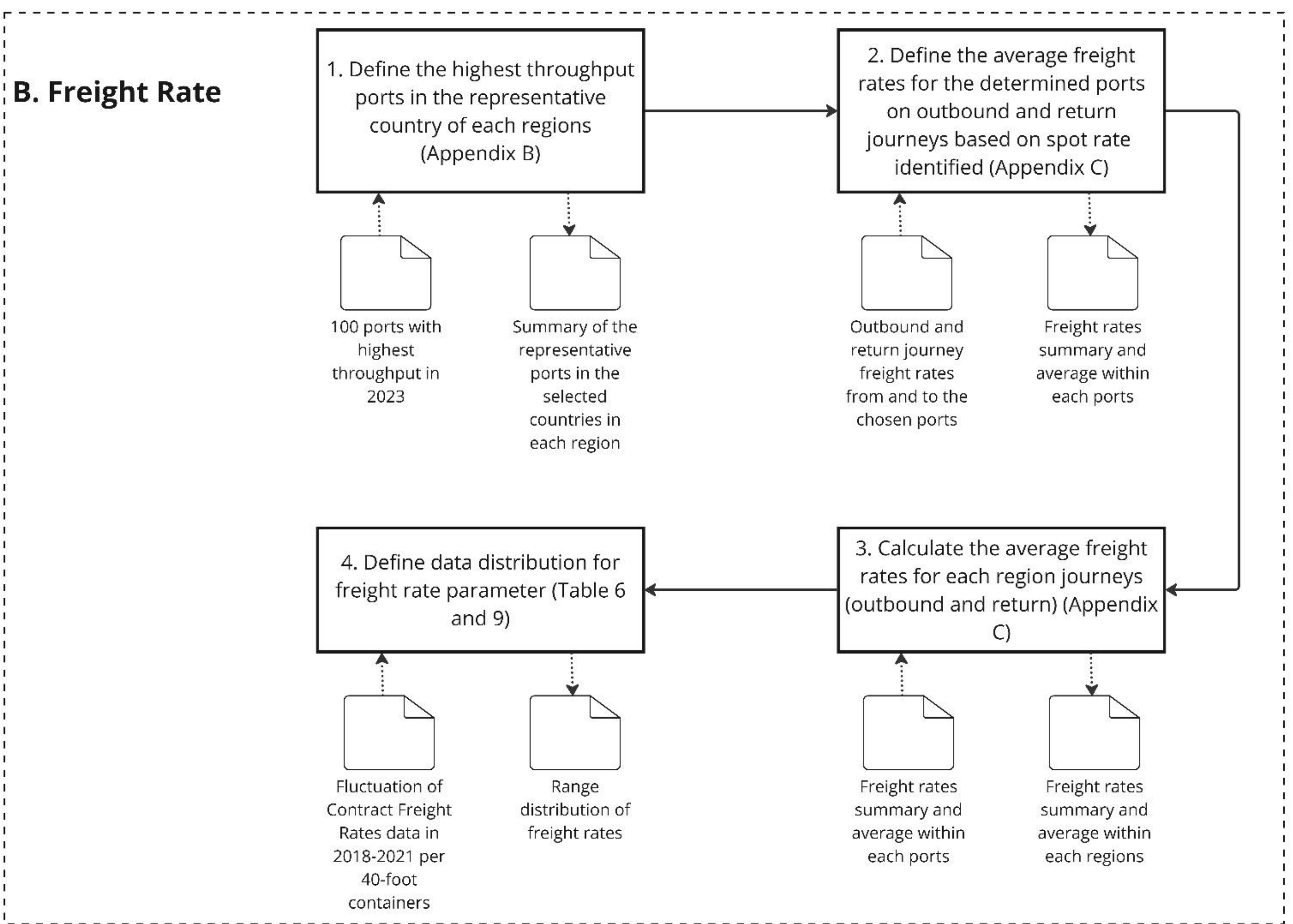


Figure 31 Approach to Generalize Freight Rates in the Case Study

The ports are determined based on their highest throughput in 2023, assuming that the higher the throughput, the higher the port contribution to the total revenue of each respective region to the overall revenue generation. The list of the top 100 ports with the highest throughput in 2023 can be seen in Appendix B.

China has the most deficits, and its five ports with the highest throughput are listed below. Other Far Eastern countries will not be considered since it will be assumed that China is the representative country for the Far Eastern region.

1. Shanghai
2. Ningbo-Zhoushan
3. Shenzhen
4. Qingdao
5. Guangzhou

The United States, which is part of the North American region, is the most surplus country. Hence, below is a list of the highest total throughput ports in the North America region:

1. Los Angeles
2. Long Beach
3. New York/New Jersey
4. Savannah
5. Houston

Brazil and Mexico are the countries with the most surplus in the South American region. Hence, below is a list of the highest total throughput ports in the Latin America region:

1. Colón
2. Santos
3. Manzanillo
4. Balboa
5. Cartagena

Africa is an alternative region to the geopolitical issue of the Red Sea. Below is a list of the highest throughput ports in Africa:

1. Tanger Med
2. Port Said
3. Durban
4. Lomé

Below is the list of the highest throughput ports in **Europe**:

1. Rotterdam
2. Antwerp-Bruges
3. Hamburg
4. Valencia
5. Piraeus

The details on the spot rate for return and outbound journeys in each region is further explained in Appendix C (GoComet, 2024.; SeaRates, 2024.). As the analysis is from the shipping industry perspective, hence the revenue calculation is as follows:

$$\boldsymbol{Total\ Revenue}_{Outbound/Return} = \boldsymbol{Freight\ Cost}_{Outbound/Return} \times \boldsymbol{Total\ Full\ TEU}_{Outbound/Return}$$

Total revenue will be calculated based on the revenue generated from the outbound and return journey. The revenue for each journey is calculated by their respective freight rate times the full TEU numbers shipped from the respective journey. That being said, if it is the outbound journey, the freight cost of the outbound journey is multiplied by the total full TEUs shipped during the outbound. In contrast, if it is a return journey, the freight cost of the return journey is multiplied by the total TEUs shipped during the return.

Alternative 1:

$$\boldsymbol{Total\ Revenue} = Total\ Revenue\ Outbound + Total\ Revenue\ Return$$

Alternative 1 will calculate the total revenue of outbound and return journeys since the focus is to identify the total revenue generated when the company focus on maintaining the export level in 2023.

Alternative 2:

$$\begin{aligned}\boldsymbol{Total\ Revenue} &= Total\ Revenue_{Outbound} + Total\ Revenue_{Return} \\ &+ Loss\ of\ Revenue\ due\ to\ Repositioning_{Outbound} \\ &+ Loss\ of\ Revenue\ due\ to\ Repositioning_{Return}\end{aligned}$$

Since there will be curtailing from regions aside from the Far East (deficit region) in this alternative, a loss of revenue will be expected from the curtailed region. That loss of revenue will be included in the revenue calculation for Far East and the curtailed region. Alternative 2's calculation consists of the "Loss of Revenue due to Repositioning" variable, which reflects the opportunity cost of choosing one alternative over another. As explained in the assumption, curtailing will only proceed for the outbound journey. Hence, the outbound journey from the region that was curtailed will incur a negative loss of revenue. Whereas the Far East region will receive positive loss revenue in their return journey since the curtailed full containers will be repositioned to the Far East, and the Far East will have additional full containers to be utilized directly for trade. Hence, it contributes to additional profit in the Far East return journey. Formulation on how to calculate the loss of revenue will be discussed in Sub-Chapter 5.4.4.

As the analysis will be performed with and without the influence of seasonality in Alternative 2, the Total Revenue formula will not be different. The difference exists because there will be different total full containers amount each month based on its trend. Hence, when the peak month comes, the freight rate will be different. The data distribution used for seasonality testing in Alternative 2 is presented in **Appendix C**.

5.4.2 Utilization Rates

Maersk's total vessel utilization rate from the EU to the Far East in 2023 was 96%, with total TEU loaded assumed at 710.000 million TEUs (**Table 11**) and operational allowance or operational vessel capacity allowed is assumed to be 882.725 million TEUs if following the formula below. With the normalization method, total empty TEU for outbound journey is 132.836 million TEUs. The aim is to take, from the 2023 trade, that if the company prioritizes the difference of operational allowance with TEU loaded, which amounted to 39.900 million TEUs for repositioning, hence, the vessel utilization of Far East – EU trade will be 100%. That said, 39.900 million TEUs of laden transactions from certain regions should be canceled and prioritized to send empty to the APA region.

In general, utilization rates are identified as below:

$$\begin{aligned}\boldsymbol{Utilization\ rate}_{Outbound/Return} &= \left(Total\ Full\ TEU_{Outbound/Return} + Total\ Empty\ TEU_{Oubtound/Return}\right) \\ &\div Operational\ Allowance_{Outbound/Return}\end{aligned}$$

Operational Allowance is the maximum capacity allowed in the vessel. The utilization rate of outbound and return rates will differ based on the total TEU of containers loaded onto the vessel during that journey and the maximum capacity of the vessel. Thus, to calculate the utilization rate of the outbound journeys, the sum of total full TEUs of the outbound journeys and total empty of outbound journey will be divided by its outbound operational allowance and the same applies for the return journey.

5.4.3 Demand in Deficit Areas

Demand in the deficit area will follow the 39.900 million TEUs required to reposition from the EU to the Far East (**Section 5.4.2**). As mentioned in Sub-Chapter 5.4.2 before, the aim is to fully utilize the outbound journey of Europe to the Far East by adding more empties to the vessel, which will be curtailed from another region. The utilization of the Far East outbound journey is 96%, with 710.000 million TEUs loaded. Hence, an additional 39.900 empties can be added to the outbound journey of the Far East, which then empties will be directly employed for the Far East return journey. **Figure 32** below represents the summary of determining the demand in deficit area.

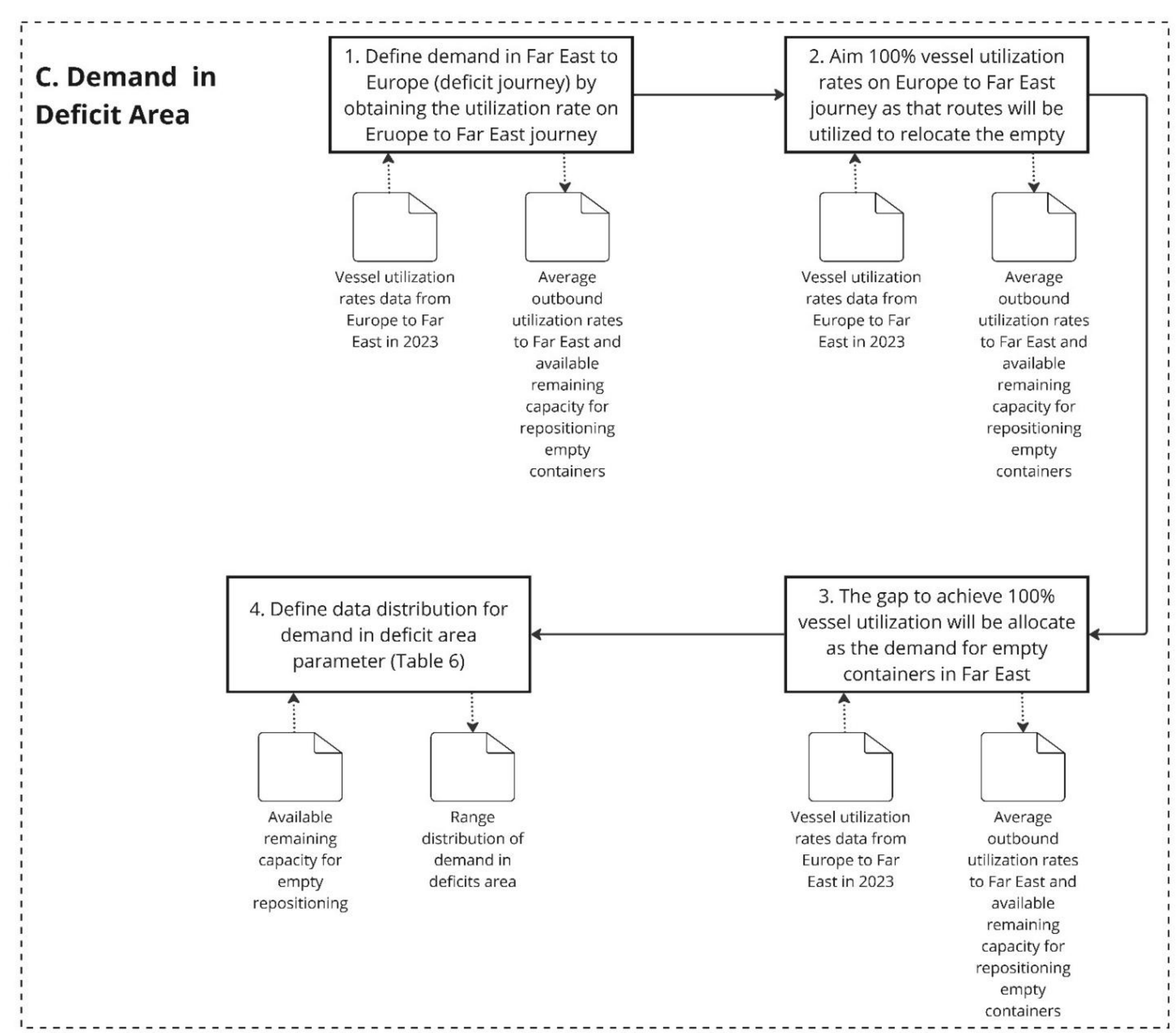


Figure 32 Approach to Generalize and Identify Demand in Deficit Area

In the context of seasonality testing, the demand in deficit area will follow the data distribution in **Appendix D**.

5.4.4 Opportunity Costs

There is a potential loss of revenue when prioritizing one strategy over another. Hence, it is crucial to calculate the loss of revenue when choosing one strategy over another due to the opportunity cost.

Alternative 1:

There is no loss of revenue since trade between regions is executed as usual, and no curtailing strategy is implemented.

Alternative 2:

$$\boldsymbol{Loss\ of\ revenue\ due\ to\ repositioning}_{Outbound/Return} = Freight\ Rate_{Outbound/Return} \times Additional\ Empties_{Outbound/Return}$$

Assuming all containers return to their respective trade lanes based on their origin, revenue loss will only affect outbound routes (EU-Latin America, EU-North America, EU-Africa) due to surpluses in these regions, with no impact on the return journey. Therefore, the loss of revenue for other areas will be zero. EU-Latin America, EU-North America, and EU-Africa will show a negative revenue loss. At the same time, the Far East to EU route will reflect a positive gain from additional revenue through empty repositioning.

5.4.5 Transit Time

Transit time, sourced from Appendix C (GoComet, 2024; SeaRates, 2024), is based on spot rates and only accounts for the duration spent in ocean transit. Variations in transit time will result in differing revenue per day and variations in daily revenue loss. **Figure 33** represents the approacg deployed to determine the transit time.

Alternative 1:

No loss of revenue per day is calculated since the trade between regions is executed as usual.

$$\boldsymbol{Total\ Revenue\ per\ Day} = (Total\ Revenue_{Outbound} \div Transit\ Time_{Outbound}) + (Total\ Revenue_{Return} \div Transit\ Time_{Return})$$

The total revenue calculated from Sub-Chapter 5.4.1 previously will be used in this calculation. Transit time will be the divisor as the study wants to analyze the total revenue per day. The total revenue of the outbound journey will be divided by the total transit time for the outbound journey. The same applies to the return journey. The total revenue per day from each journey will be summed up and generate the final amount of total revenue per day.

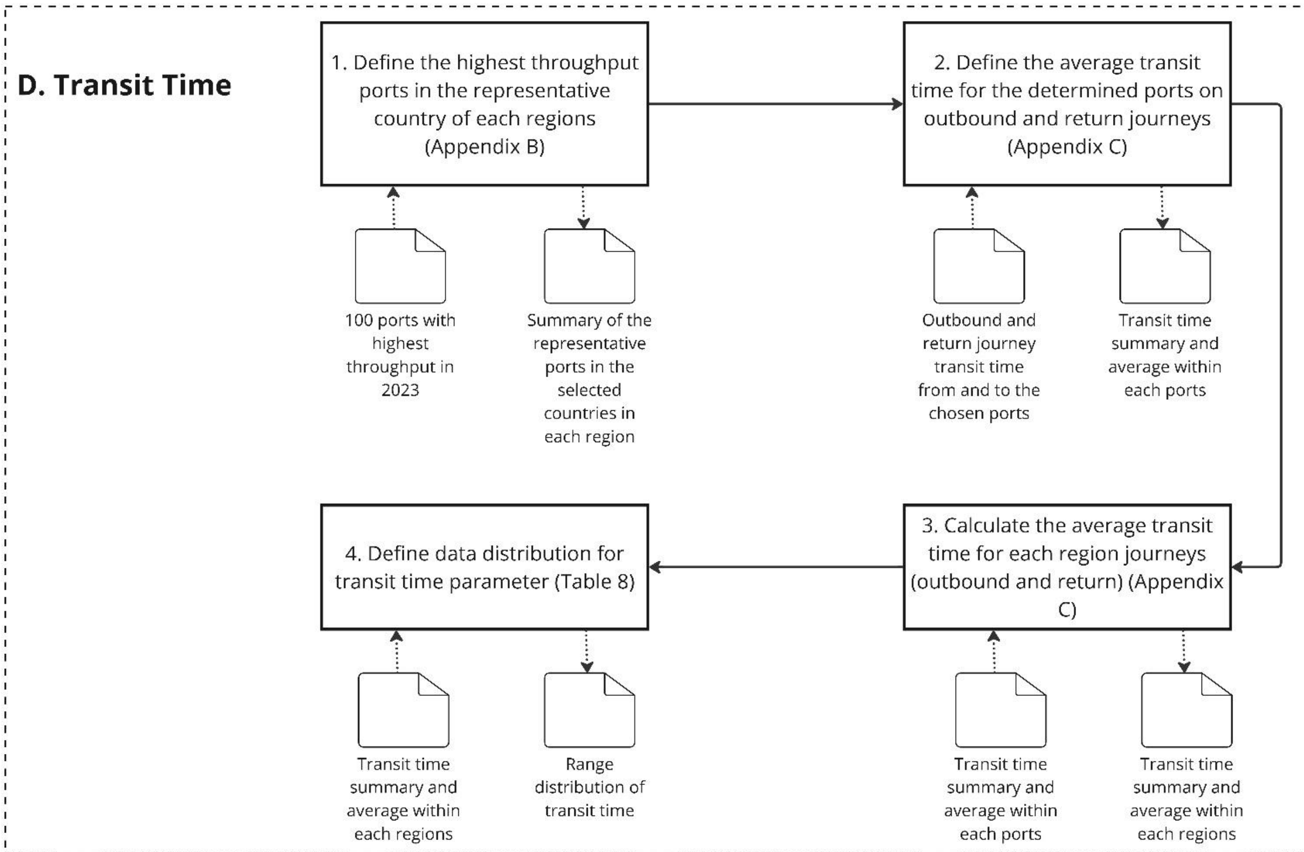


Figure 33 Approach to Generalize Transit Time in the Case Study

Alternative 2:

As explained in Sub-Chapter 5.4.1, due to the curtailing, the curtailed region will experience a loss of revenue. This loss of revenue will be quantified on a daily basis as well by dividing it by its transit time. Loss of revenue due to repositioning on the outbound journey will be divided by outbound transit time, and loss of revenue from a return journey will be divided by return transit time. The total loss of revenue per day from outbound and return will be added up, generating a loss of revenue due to repositioning per day, as the formula below explains.

$$\boldsymbol{Loss\ of\ Revenue\ due\ to\ Repositioning\ per\ day}_{Outbound/Return} = Loss\ of\ revenue\ due\ to\ repositioning_{Outbound/Return} \div Transit\ Time_{Outbound/Return}$$

In addition, total revenue per day will also be calculated in Alternative 2. Total revenue outbound and return will be divided by its respective transit time, and both journey's amounts will be totaled, then adding up its loss of revenue per respective journey, resulting in total revenue per day for alternative 2.

$$\boldsymbol{Total\ Revenue\ per\ Day} = (Total\ Revenue_{Outbound} \div Transit\ Time_{Outbound}) + (Total\ Revenue_{Return} \div Transit\ Time_{Return}) + (Loss\ of\ revenue\ due\ to\ Repositioning_{Outbound/Return} \div Transit\ Time_{Outbound/Return})$$

The formula has been adjusted based on discussions with the Equipment Flow Team as the representative in conducting this case study. If in the future any shipping companies want to perform this model, they can tailored the formula of the parameters, in the comment **"#Helper function to calculate revenue and losses for the region pair**" in accordance with **Appendix G, H** and **I**.

5.5 Sub-Conclusion

The year 2023 stands out as a pivotal period for the shipping market, marking a return to stable and normalized sales trends reminiscent of pre-pandemic conditions. Based on global data and insights from Maersk, notable observations include the Far East region (with China as a representative example) being the most deficit-prone, while North America, particularly the United States, emerges as the most surplus region. Additionally, the European Union's commodity trade predominantly features the export of chemicals and machinery products, although the region remains heavily dependent on energy-related imports.

The regions analyzed include the Far East (deficit region), North America and Latin America (surplus regions), and Africa, which has been included for its potential future revenue generation within global maritime trade. Approximately 12% of global trade was rerouted through Africa due to the Red Sea crisis, highlighting its strategic significance.

Two primary alternatives are proposed for analysis:

1. Maintain the current EU exports to the Far East, Africa, Latin America (LAM), and North America (NAM), while keeping utilization rates at their existing levels.
2. Curtail EU exports to Africa, LAM, and NAM by prioritizing the import return of empty containers to the Far East. This strategy involves canceling the export of laden containers to these three regions to enhance the availability of empty containers for shipments to the Far East.

Within alternative 2, additional scenarios are considered:

1. Curtail full containers from Africa's outbound journey.
2. Curtail full containers from Latin America's outbound journey.
3. Curtail full containers from North America's outbound journey.
4. Curtail full containers from a combination of Africa, North America, and Latin America.

Alternative 2 will analyze the impact of seasonality. Without seasonality, calculations focus on the full year. When seasonality applies, monthly trends are assessed first, then aggregated into a yearly total. This total is compared against Alternative 1 and Alternative 2 without seasonality, providing deeper insights into demand fluctuations and their overall impact on the analysis.

Several assumptions underpin the model, with key analysis parameters identified. The independent variables include freight rate, demand in deficit regions, utilization rates, opportunity costs, and transit time. The dependent variables encompass total revenue, total revenue per day, loss of revenue due to repositioning, and loss of revenue per day attributable to repositioning.

6. Case Study of Maersk- Model Implementation and Interpretation

The revenue model can be applied to real-world scenarios by inputting relevant data (e.g., real-time freight rates, specific regional demands, transit times) into the Monte Carlo simulation. This allows companies to simulate various scenarios to see potential revenue outcomes, assess the correlation of each parameter and parameter distribution, and make informed decisions on container allocation.

The model developed for evaluating revenue in empty container repositioning can be applied to any shipping company, particularly those triggered by trade imbalances involving shipping routes with surplus and deficit regions. The model factors in significant variables such as freight rates, container utilization, demand in deficit areas, opportunity costs, and transit time, which are recurrent issues in trade imbalances. Given its structure, this model appears versatile and could be adaptable to scenarios where trade imbalances play a critical role, allowing it to be applied multiple times as long as the focus remains on similar logistics and revenue factors.

The model's use of Monte Carlo simulations and scenario analysis provides robustness, enabling it to account for variability across trade lanes and economic conditions. This adaptability makes it suitable for repeated application in future analyses where comparable conditions are present, such as fluctuating demand, strategic container repositioning, or shifts in shipping costs.

The defined alternatives and scenarios will be analyzed in this section. Finally, the result will be interpreted to understand the effect of each alternative and scenario on shipping industry revenue.

The dependent variables are total revenue, total revenue per day, loss of revenue due to repositioning, and loss of revenue due to repositioning per day. The variations of the independent variables influence the dependent variables explained previously.

The analysis will employ Monte Carlo simulations to assess the impact of independent variables on the dependent variables through 500 iterations. The study will use Python scripts, as Appendices G, H and I detailed.

To analyze data and derive insights, the thesis project uses two primary types of visualizations, namely, histograms and heatmaps.

6.1 Alternative 1- Maintaining Maersk's Current Business Approach

Alternative 1 study the past strategy performed in Maersk in 2023 with no changes implemented in this alternative. The study will identify the revenue in 2023 based on the implemented strategy with the determined parameters that have been defined previously (Chapter 5).

6.1.1 Analysis based on Histogram Visualization

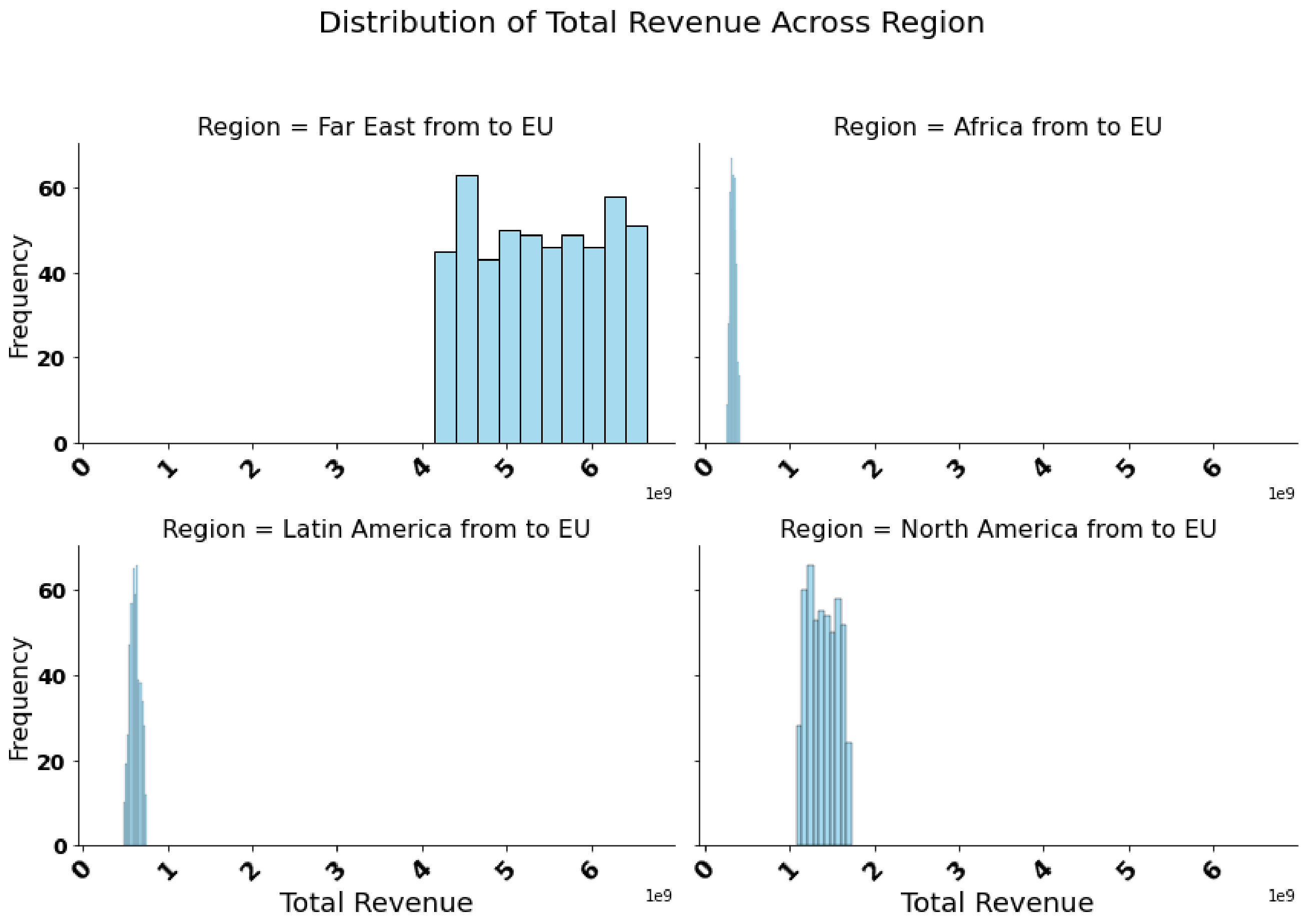


Figure 34 Distribution of Total Revenue Across Region (in Billion Dollars)

The simulation results indicate the **average total revenue** for each region as follows: 1) **Far East**, with an average of 5.41 billion dollars; 2) **Africa**, with an average of 0.33 billion dollars; 3) **Latin America**, with an average of 0.62 billion dollars; and 4) **North America**, with an average of 1.5 billion dollars. The **average total revenue across regions** is **7.76 billion dollars**, calculated as the sum of the average total revenue from every region.

In addition to that, the analysis shows that for Europe, **total** outbound and return journeys' **revenue** in Africa, Latin America, and North America have skewed distributions, with total revenue concentrated at lower values, indicating smaller revenue in trade with the EU. The distributions spread between amounts of zero to one billion dollars. **North America** has the tendency for total revenue combined with outbound and return journeys ***between 1 and 2***, while **Latin America** is ***near to one*** and **Africa** is in the middle of ***0 and 1***. That being said, the range of the revenue is lower since it is clustered in one area only in histogram.

In contrast, the **Far East** displays a broader revenue range (***between 4 and above 6***), suggesting a higher potential for larger revenue. These regions show significant differences, with the Far East exhibiting more variability and potential for greater financial outcomes than the consistently lower revenues observed in the other regions. The conclusion comes from the frequency inconsistency that appeared within the range of the total revenue.

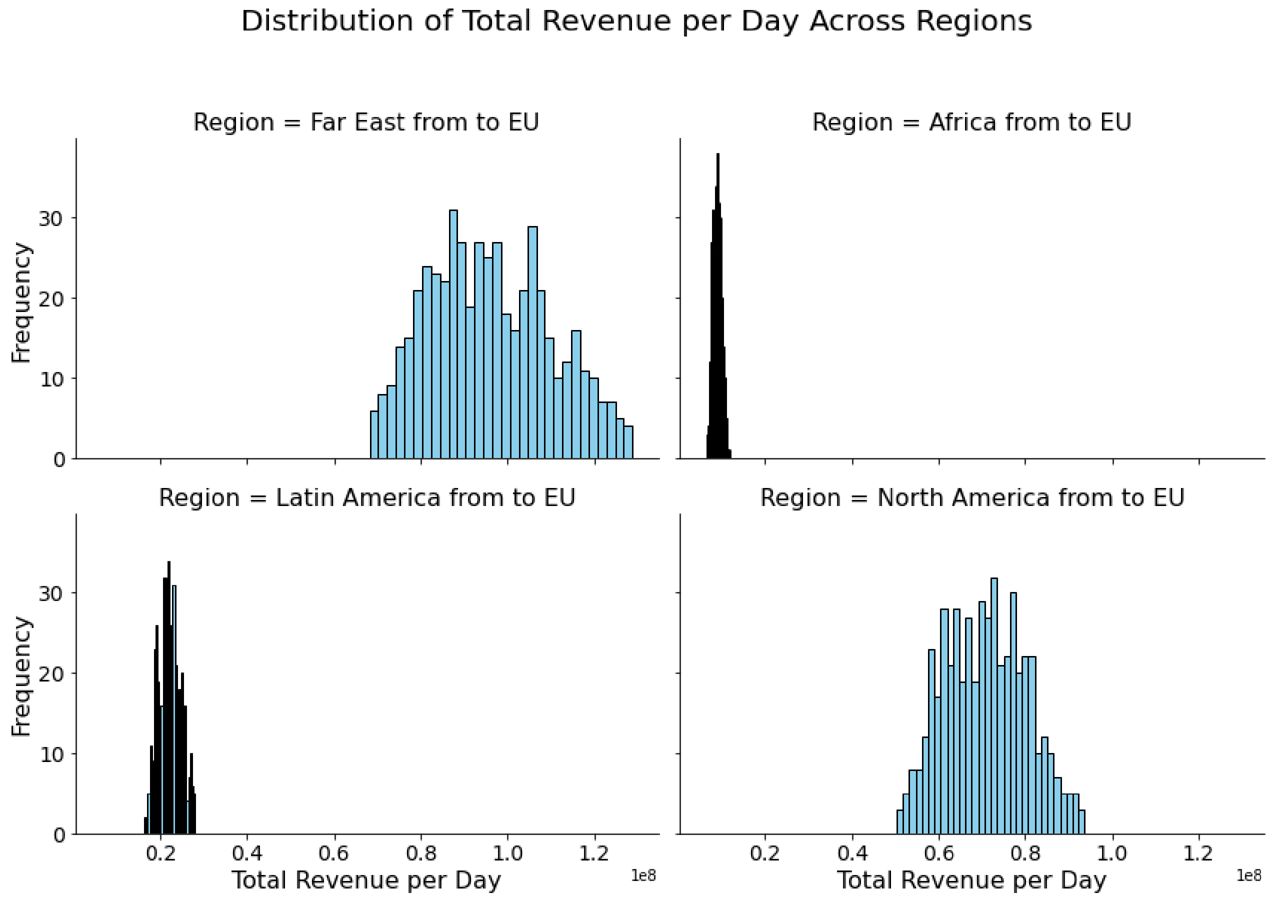


Figure 35 Distribution of Total Revenue Per Day Across the Region (in One Hundred Million)

In terms of **Total Revenue per Day** in the European outbound and return journeys, Far East and North America route shows a broader daily revenue, with **Far East** ranging from ***60 million to 120 million***, and **North America** ranging for ***50 million to 93 million*** suggesting greater variability and potential for larger revenues per daily basis. In contrast, **Africa** and **Latin America** have distributions concentrated around ***20 million***, indicating consistently low daily revenues with minimal variation. These regions show similar revenue dynamics, characterized by smaller, less variable revenues compared to the Far East and North America, which exhibits a wider range of financial outcomes.

6.1.2 Analysis based on Heatmap Visualization

Figure 36 Correlation Heatmap Across Region

The first analysis will be performed at macro-level across regions. Freight rate per TEU in outbound journeys from all regions to Europe (**Figure 36**) depicts a strong negative impact on total revenue and moderate negative impact total revenue per day, which is indicated by the purple color and correlation amount of each -0.79 (purple) and -0.56 (purple). An increase in the outbound freight rate will result in lower total revenue and total revenue per day. Freight rate outbound journey (-0.82) also shows a strong negative correlation with the freight rate return journey. That being said, an increase in the outbound freight rate will cause a decrease in the return freight rate and vice versa. In addition, the freight rate outbound demonstrates a strong correlation with average transit days of outbound (-0.76) and moderate correlation to transit days of return (-0.61) journeys. The result implies the increase in return freight rate will decrease the average transit day return and outbound journeys and vice versa.

The freight rate of return journey also indicates moderate to strong positive correlation (green to yellow color) with the other parameters. That means an increase in freight rate returns will also increase the amount of average transit days return (0.82) and outbound (0.90), as well as the total revenue (0.84) and total revenue per day (0.52).

Average transit day on an outbound journey shows a strong positive correlation with return average transit day (0.95), total revenue (0.82), and moderate positive correlation with total revenue (0.44) per day, which is indicated by the green to yellow color. In other words, an increase in the average transit day of an outbound journey will also raise the average transit day of return, total revenue, and total revenue per day.

Further detailed analysis will be performed per region to identify if there are any differences in the correlation if we look deeper. In the Far East to EU region (**Figure 37**), the result on outbound rates depicted different results with the overall region result with a negative correlation of little to no correlation to revenue. However, there are slight differences in the outbound and return rates correlation. Where analysis of the overall region shows that there is a strong negative correlation, Far East region shows little to no correlation between outbound and return rates. The heatmap result also supported that return rates from the Far East to Europe have a strong correlation with the total revenue generated (yellow, 1.00) and a strong positive correlation with total revenue per day (green, 0.91). In contrast, average transit days outbound have weak to no correlation with total revenue (purple, 0.04) and total revenue per day (purple, 0.02). The same applies to average transit time return with total revenue (purple, 0.04). However, the heatmaps show a moderate negative correlation between average transit time return and total revenue per day (purple, -0.37). Meaning that an increase in average transit time return will increase the total revenue per day. Since the average transit time return and outbound rate have weak negative correlations, and return rate positively correlated with total revenue per day, any increase in average transit time return will decrease the freight rate return and total revenue per day, and vice versa.

The same with Far East, outbound and return freight (purple, 0.01) rates show little to no correlation as well in Africa and Europe trade (**Figure 38**). While the result remains the same with Far East, return and outbound rates show little to no correlation with average transit days return (purple, 0.03; purple, -0.04) and outbound (purple, --0.02; purple, 0.02) journeys. Outbound rates have a strong positive correlation with total revenue (green, 0.88) and total revenue per day (green, 0.81) compared to the return rates (green, 0.48; green, 0.42), which have moderate positive correlations. As for the average transit days return and outbound, it shows little to no correlation with the total revenue (purple, -0.02; purple, 0.01). While the result differs between average transit days return with total revenue per day which shows a weak negative correlation with total revenue per day (purple, -0.21), in contrast with the negative moderate correlation between average transit days outbound with total revenue per day (purple, -0.36).

Figure 37 Correlation Heatmap from Far East from to EU,

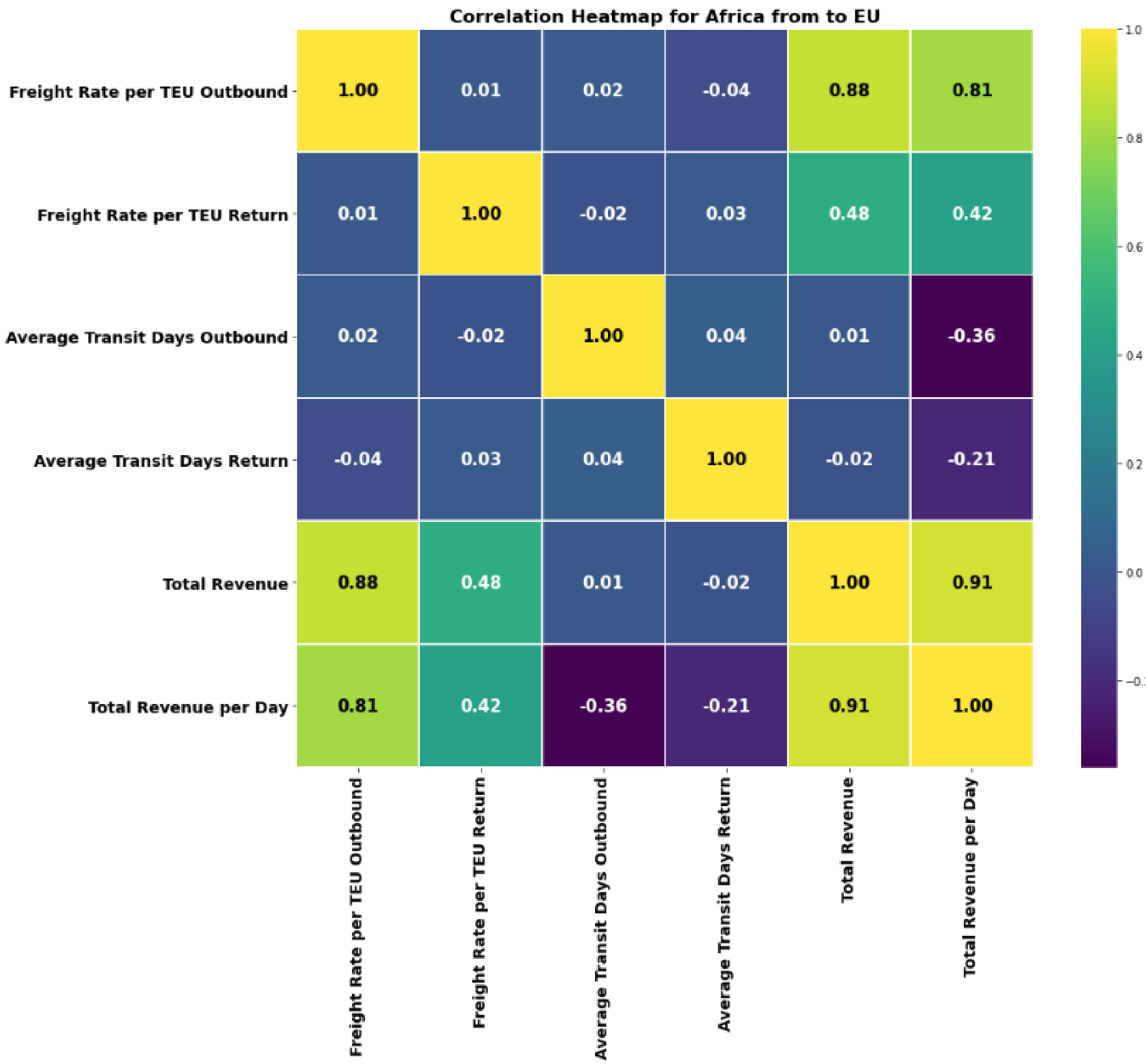


Figure 38 Correlation Heatmap from Africa from to EU

Figure 39 Correlation Heatmap from Latin America from to EU

Return and outbound rates still depict little to no correlation with the average transit time of return and outbound journeys in Latin America and EU trade (**Figure 39**). Freight rate return and outbound describe the same result with Far East and Africa, which has little to no correlation (purple, 0.04). Return rates show a strong positive correlation with total revenue and total revenue per day (green, 0.80; green, 0.78) contrasting with Africa which only moderate correlation, but the same result with Far East. In addition, the outbound rates still depict a moderate positive correlation with total revenue (green, 0.62) and total revenue per day (green, 0.50). Average days return (purple, -0.06) and outbound (purple, 0.02) have little to no correlation with total revenue. Average transit days outbound has a weak negative correlation with total revenue per day (purple, -0.20) and average transit days outbound with a weak negative correlation (purple, 0.02). This indicates that the increase in average transit time return and outbound will decrease total revenue per day, which will result in a decrease in return and outbound rates.

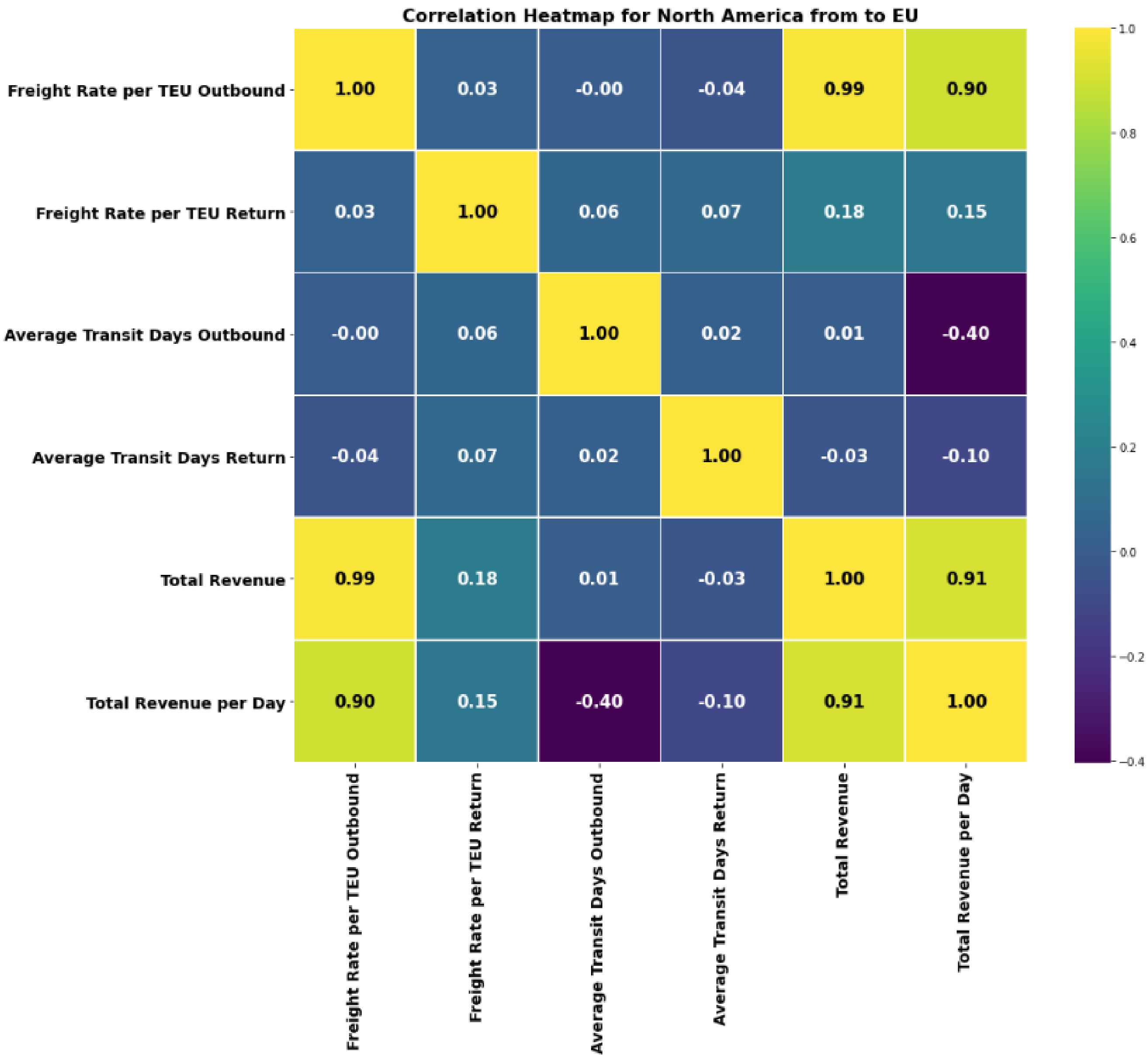


Figure 40 Correlation Heatmap from North America from to EU

Return and outbound rates still depict little to no correlation with the average transit time of return and outbound journeys in North America and EU trade as well (**Figure 40**). Freight rate return and outbound describe the same result with Far East, Africa, and Latin America, with little to no correlation (purple, 0.03). Return rates show a weak positive correlation with total revenue (blue, 0.18) and total revenue per day (blue, 0.15), contrasting with Africa, Far East, Latin America, and overall region analysis which shows moderate to strong correlation. In addition, the outbound rates depict a positive strong correlation with total revenue (yellow, 0.99) and total revenue per day (green, 0.90), similar as the overall region result but opposite of Far East which show little to no correlation.

Average days return (blue, -0.03) and outbound (blue, -0.01) have little to no correlation with total revenue. However, average transit days outbound has a moderate negative correlation with total revenue per day (purple, -0.40) but little to no correlation with total revenue (purple, 0.01). This indicates that the increase in average transit time outbound will decrease total revenue per day, which will result in a decreasing amount in return rates.

6.1.3 Key Findings in Alternative 1

Based on the **histogram analysis**, *average total revenue across European regions is 7.76 billion dollars*. However, Africa, Latin America, and North America have skewed distributions, with revenue concentrated at lower values, indicating smaller trade with the EU. North America tends to have total revenue between 1 and 2, while Latin America and Africa are clustered in one area below zero. Far East has a broader revenue range, suggesting greater potential for larger revenue. Far East and North America regions show greater variability and potential for larger daily revenues, while Africa and Latin America have low daily revenues with minimal variation.

Table 12 summarizes the range of revenue for Total Revenue and Total Revenue per Day for alternative 1

Table 12 Data Range of Total Revenue And Total Revenue per Day – Alternative 1

Region	Key Parameters	Alternative 1 – Data Range
Far East from to EU	Total Revenue	4.1 to 6.7 billion
	Total Revenue per Day	60 million to 120 million
Africa from to EU	Total Revenue	0.26 to 0.4 billion
	Total Revenue per Day	6 to 12 million
Latin America from to EU	Total Revenue	0.47 to 0.75 billion
	Total Revenue per Day	16 to 28 million
North America from to EU	Total Revenue	1.1 to 1.7 billion

Additionally, **heatmap analysis** shows that the across region analysis indicates that the change in return freight rate will influence average transit days outbound and returns, total revenue and total revenue per day in a positive direction. While outbound rate will influence the other parameters in a negative direction. In addition, total revenue and total revenue per day are affected by the return and outbound rate, and average transit day return and outbound. However, the outbound rate negatively influences the revenue outcome. Thus, to maintain optimum revenue at macro level, it is essential to manage the return rates, outbound rates and average transit day outbound.

Deeper analysis on region-based shows varied insights on the parameters. Analysis in **Far East** region identifies that total revenue and total revenue per day is perfectly influenced by return rates in Far East. Thus, high return rates will generate high revenue outcome. In contrast, high average transit time return will decrease the total revenue per day. Hence, it is important to maintain high return rates and minimum average transit time return in order to achieve high revenue outcome.

Africa shows that outbound and return rates affect total revenue and total revenue per day. However, outbound rates have a higher degree of influence on revenue outcomes. Moreover, average transit days outbound negatively impact total revenue per day. Hence, it is important to maintain high outbound and return rates and low average transit days outbound to attain higher revenue outcomes.

Latin America indicates that total revenue and total revenue per day is highly affected by return and outbound rates. In addition, total revenue per day is affected negatively by average transit days return. Therefore, to maintain high total revenue and total revenue per day, it is important to maintain the optimum return and outbound rates, as well as low average transit days return to maintain high total revenue per day.

Finally, **North America** signifies different results as Africa, Far East and Latin America where return rates implies little to no correlation total revenue and total revenue per day in this region. The revenue driver in North America is the outbound journey where it strongly correlates with the revenue implication. However, average transit days outbound negatively impact the total revenue per day. Thus, maintaining high outbound rates and low average transit days return will aid in achieving higher revenue outcomes.

6.2 Alternative 2- Prioritizing Empty Container Deployment to Deficit Regions

Alternative 2 examines if the strategies in the past year (2023) are replaced by prioritizing the empties to the deficit region, Far East. To do that, trade that occurred in 2023 on the outbound journey will be curtailed and prioritized to be repositioned to Far East. There will be four scenarios (**Figure 29**) explored in this alternative since there are many options from where the full containers will be curtailed.

6.2.1 Analysis based on Histogram Visualization (Without Seasonality)

The simulation results indicate the average total revenues for each region per scenario as follows:

1. **Scenario 1**, a) **Far East**, with an average of 5.402 billion dollars; b) **Africa**, with an average of 0.29 billion dollars; c) **Latin America**, with an average of 0.617 billion dollars; and d) **North America**, with an average of 1.405 billion dollars. The **average total revenue across regions** is **7.71 billion dollars**, calculated as the sum of the average total revenue from every region.
2. **Scenario 2**, a) **Far East**, with an average of 5.423 billion dollars; b) **Africa**, with an average of 0.333 billion dollars; c) **Latin America**, with an average of 0.594 billion dollars; and d) **North America**, with an average of 1.404 billion dollars. The **average total revenue across regions** is **7.75 billion dollars**, calculated as the sum of the average total revenue from every region.
3. **Scenario 3**, a) **Far East**, with an average of 5.405 billion dollars; b) **Africa**, with an average of 0.333 billion dollars; c) **Latin America**, with an average of 0.617 billion dollars; and d) **North America**, with an average of 1.366 billion dollars. The **average total revenue across regions** is **7.72 billion dollars**, calculated as the sum of the average total revenue from every region.
4. **Scenario 4**, a) **Far East**, with an average of 5.411 billion dollars; b) **Africa**, with an average of 0.319 billion dollars; c) **Latin America**, with an average of 0.609 billion dollars; and d) **North America**, with an average of 1.392 billion dollars. The **average total revenue across regions** is **7.73 billion dollars**, calculated as the sum of the average total revenue from every region.

Furthermore, based on **Figure 41** The ***total revenue per day*** from return and outbound journeys in **Far East**, which ranges from ***64 to 133 million dollars in each scenario***, indicates more variety and a higher total revenue per day than in other regions, regardless of which location it will be curtailed from. Additionally, the range remains rather constant regardless of the locations from where the empties were moved to the Far East.

Total revenue per day from return and outbound in **Africa** trade significantly changes in range when it is curtailed from Africa which is between ***4.72 and 12 million dollars*** in Scenario 1 and **5.8 and 12 million dollars** in Scenario 4 and indicates higher variability compared to Alternative 1 (refer to Appendix K, min and max amount of Africa). The range of total revenue per day remains unaffected when the curtailment is not from Africa. It is worth noting that in the case of curtailing, the changes only occur in minimal value, while maximal value remains unaffected.

In the case of Latin and North America, when the full containers are curtailed from their region, the range and distribution of total revenue slightly changes compared to Alternative 1, with **Latin America** ranging from nearly ***15 to 30 million dollars*** (refer to Appendix K, min and max amount of Latin America) and **North America** (refer to Appendix K, min and max amount of North America) ranging between ***47 to 98 million dollars***. However, North America shows variability in their distributions due to the more skewed distribution. In contrast with Africa, the minimal value decreases but the maximal value also increases in the context of curtailing from Latin and North America. This condition makes the range of total revenue per day in Latin and North America larger compared to Alternative 1. In conclusion, the Far East and North America, in general, have high variability but contribute significant total revenue per day compared to Africa and Latin America.

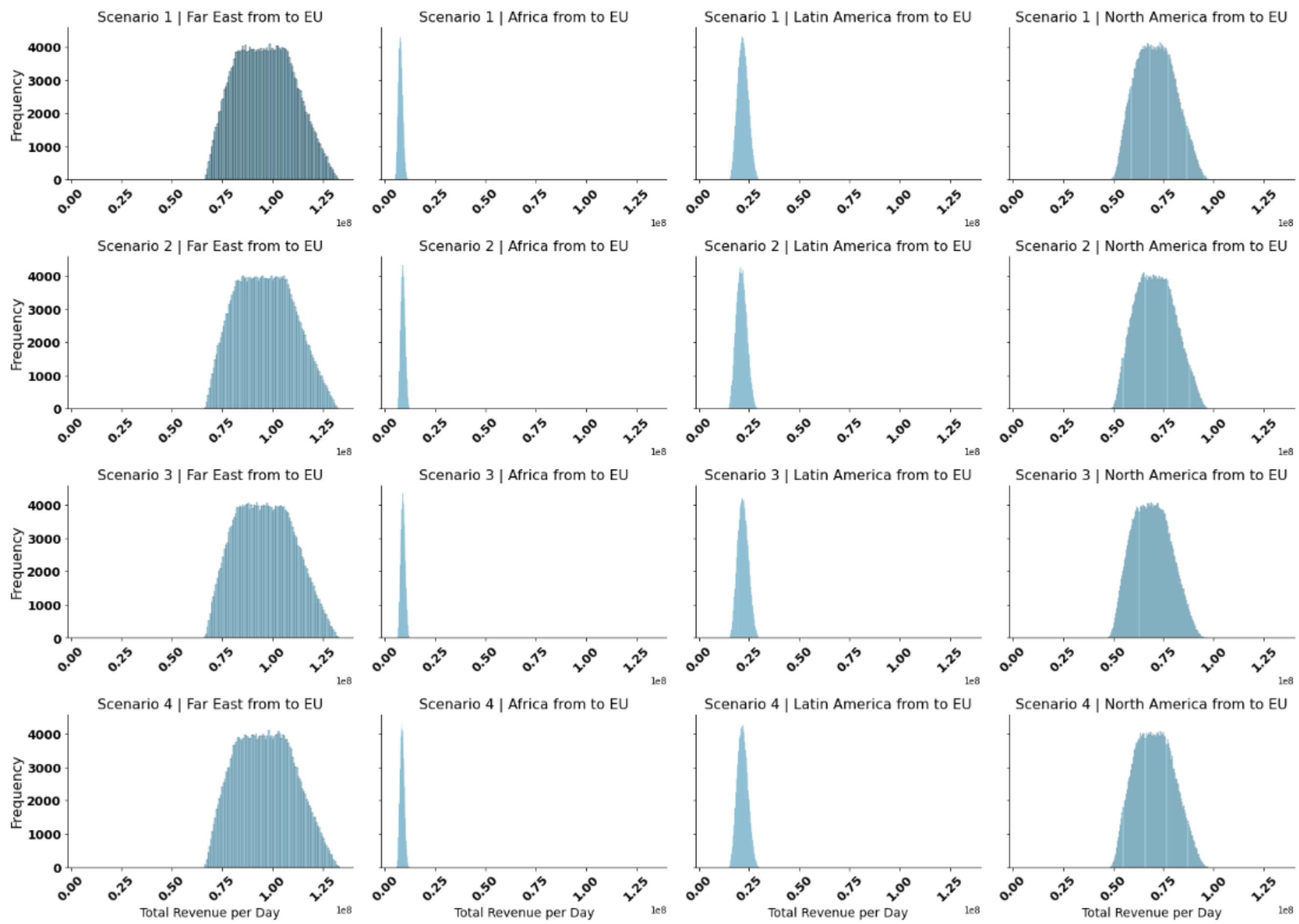


Figure 41 Distribution of Total Revenue per Day Across Regions and Scenarios (in One Hundred Million)

The analysis in **Figure 42** on ***total revenue*** across regions demonstrate that **Far East** (ranging from ***4 to 6 billion dollars***) and **North America** (ranging from ***1 to 1.7 billion dollars***) contribute the highest total revenue overall regardless of the prioritizing scheme but with minimal variability compared to Alternative 1 due to similar frequencies of occurrence. In the case of **Africa**, the total revenue ranges from ***0.2 to 0.4 billion dollars*** (refer to Appendix K, min and max amount of Africa) with high variability identified due to the more skewed distribution. The same applies to **Latin America**, but the range is ***0.44 to 0.76 billion dollars*** (refer to Appendix K, min and max amount of Latin America). Africa and Latin America show a slight change in their lower range value when the curtailment is from their region. While Africa shows no change in the upper value compared to Alternative 1, Latin America shows a slight increase in the upper value of its total revenue. Far East and North America seem not to significantly impact on the overall total revenue, despite the curtailment.

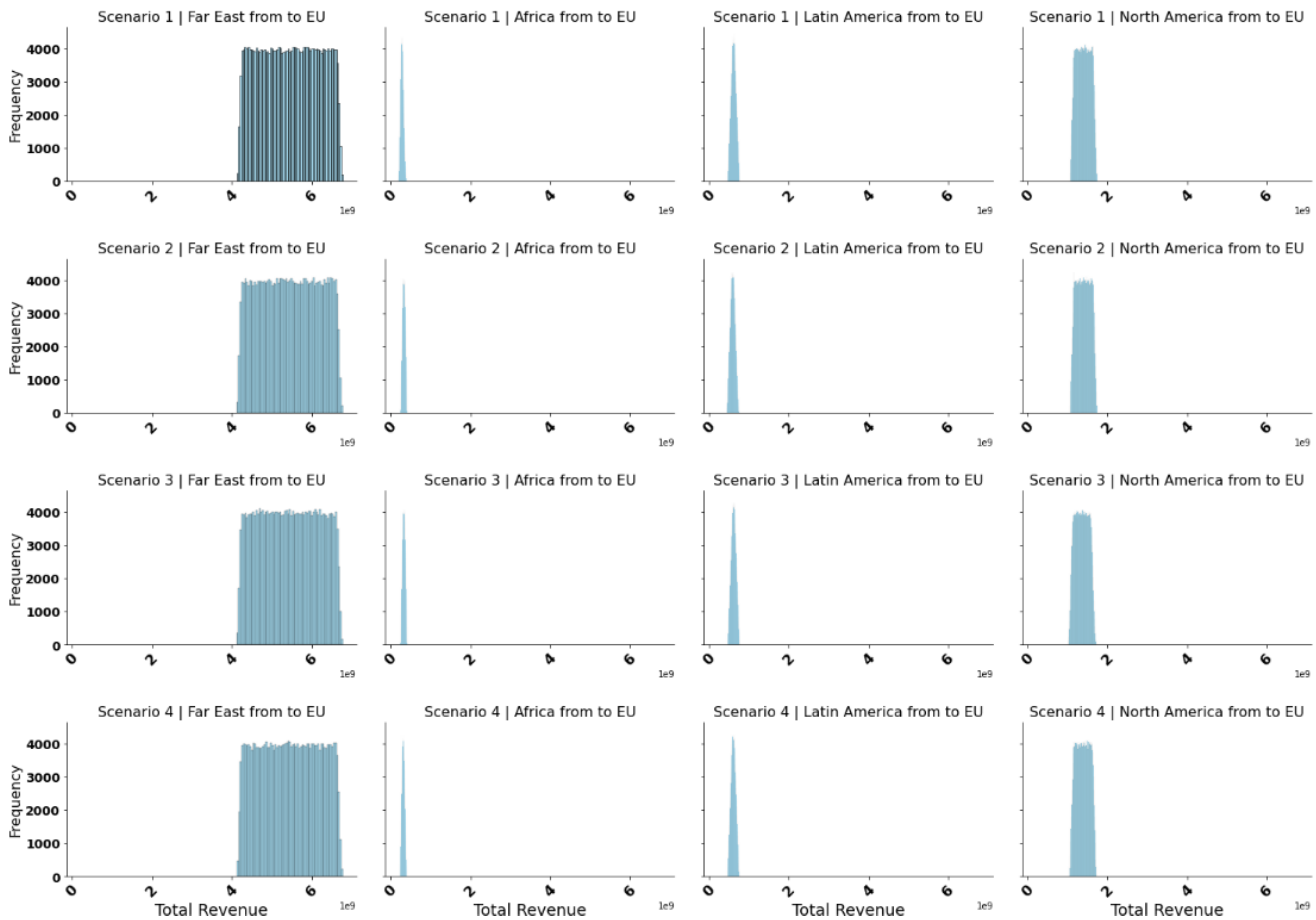


Figure 42 Distribution of Total Revenue Across Regions and Scenarios (in Billion Dollars)

When comparing the results of **Figure 41** (Total Revenue Per Day) with those in **Figure 43** (**Loss of Revenue Per Day**), the losses incurred are relatively minor in comparison to the total revenues generated across regions and scenarios. This happens due to the small number of empties repositioned compared to the full containers. The Far East is experiencing positive lost revenue since it gains extra revenue by delaying outbound flow to other regions by curtailing. In contrast with the remaining regions, they suffer the negative lost revenue since the trade that is supposedly being in their regions is curtailed. The Far East still has a high variability in the positive loss of revenue in each scenario, ranging from 0 to 2 million dollars. At the same time, North America is suffering from a high variability of loss of revenue when the full containers are curtailed from their regions and a combination of the three regions. This happens due to the high revenue contribution of North America compared to Africa and Latin America.

Similarly, in **Figure 44**, the **total loss of revenue due to prioritizing empty repositioning** to deficit areas (Far East) is negligible when compared to the Total Revenue depicted in **Figure 42**. The result depicted is the same as what is illustrated in the total Loss of Revenue Per Day. Far East gains additional revenue ranging from 6 million to 0.1 billion.

These observations suggest that the impact of revenue losses due to empty repositioning remains insignificant relative to overall revenue. This outcome may be attributed to the relatively low volume of empty TEUs repositioned compared to the total full TEUs shipped, which generate the majority of the revenue. The smaller proportion of empty repositioning likely minimizes its impact on overall revenue, thereby reducing the significance of the associated revenue losses. Consequently, the total losses due to empty repositioning remain minimal relative to the substantial revenues earned from full container shipments.

The **utilization rate outbound** of the Far East in (Figure **45**) each scenario remains constant, ranging around 96% to 100% due to the goal of achieving 100% by prioritizing the deficit region. The box-shaped diagram in Africa, Latin America, and North America occurs when there are no empties curtailed from their region; hence, the utilization rate remains constant with no changes. There will be shifting in utilization rate when the full containers are curtailed from their region. High variation in utilization rates in Africa is notable when there are full containers curtailed from Africa. When the curtailing is only from Africa, the variation ranges from 52% to 76%. In contrast with Latin and North America, they are not sensitive to curtailing full containers in their utilization rates.

There are no changes in the **return utilization rate** (**Figure 46**) in Africa, Latin America, and North America since the assumption was made that curtailing full containers will only be made for the outbound journey since it is assumed that all the vessels will come back to their origin and the demand for the return journey will not be affected by the curtailing process. Only Far East will be impacted by the curtailing process since the additional empties available for their return journey will be increased due to the repositioning, resulting in higher utilization rates of nearly 100%.

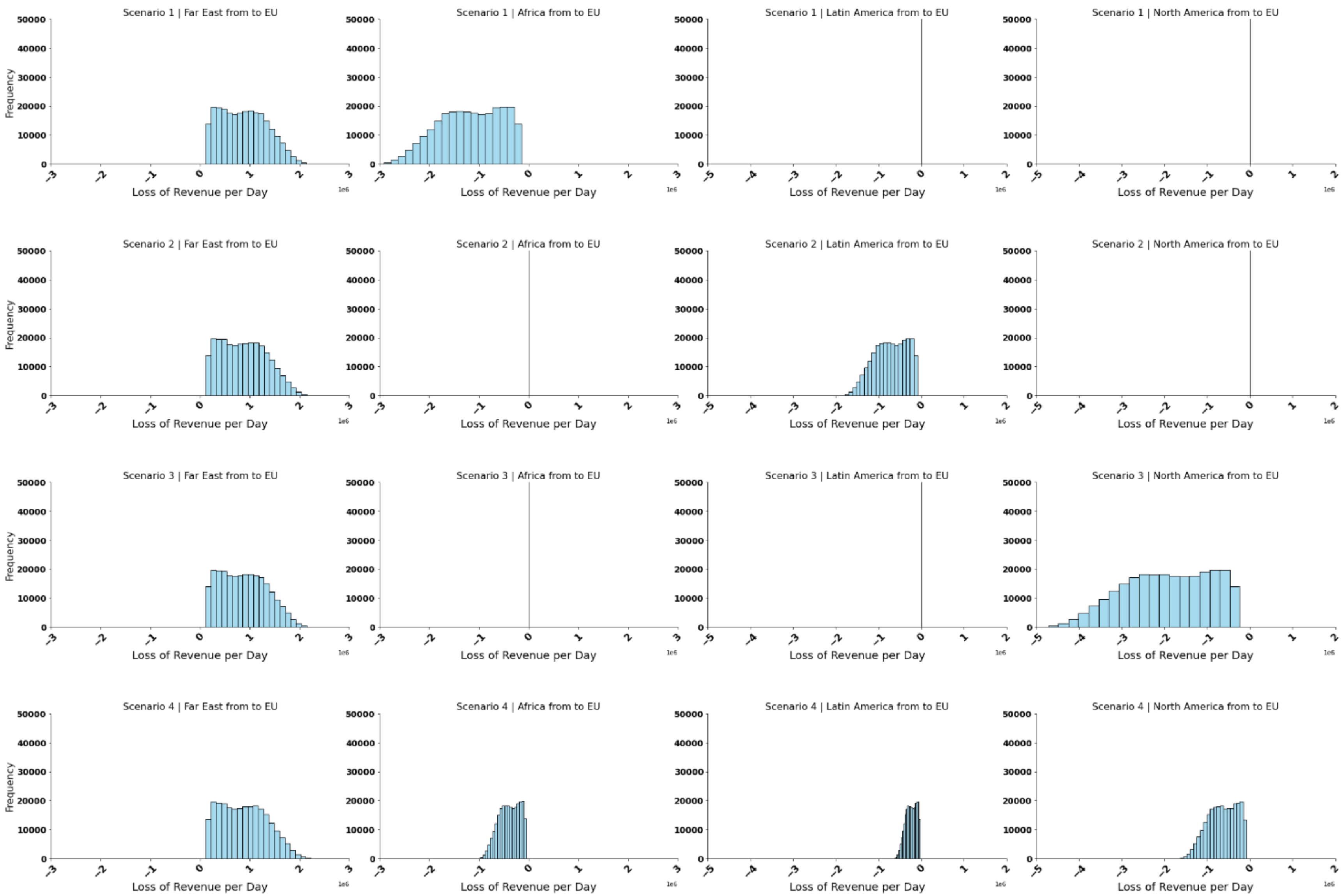


Figure 43 Distribution of Loss of Revenue Per Day Across Regions and Scenarios (in Million Dollars)

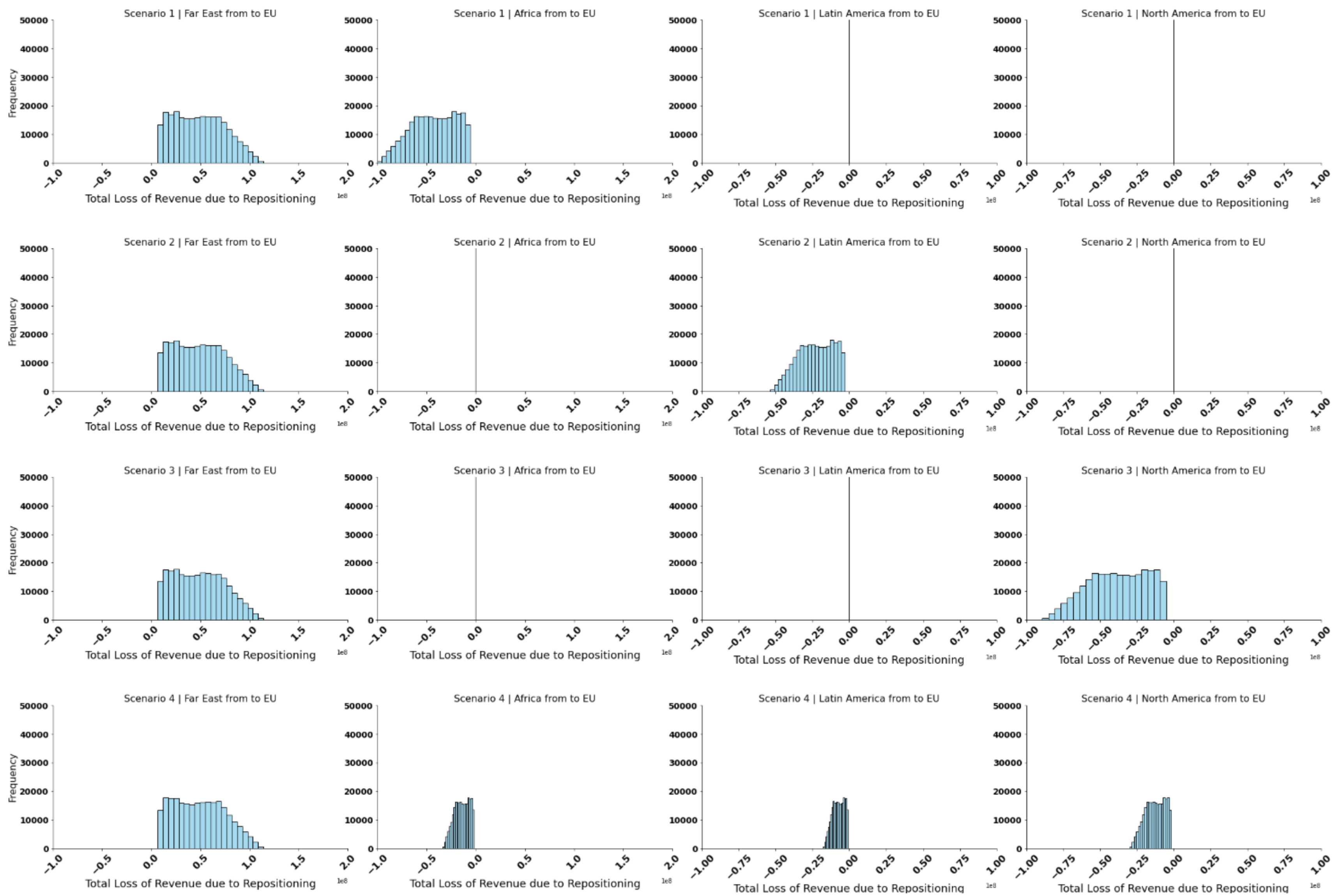


Figure 44 Distribution of Loss of Revenue Across Regions and Scenarios (in Hundred Million Dollars)

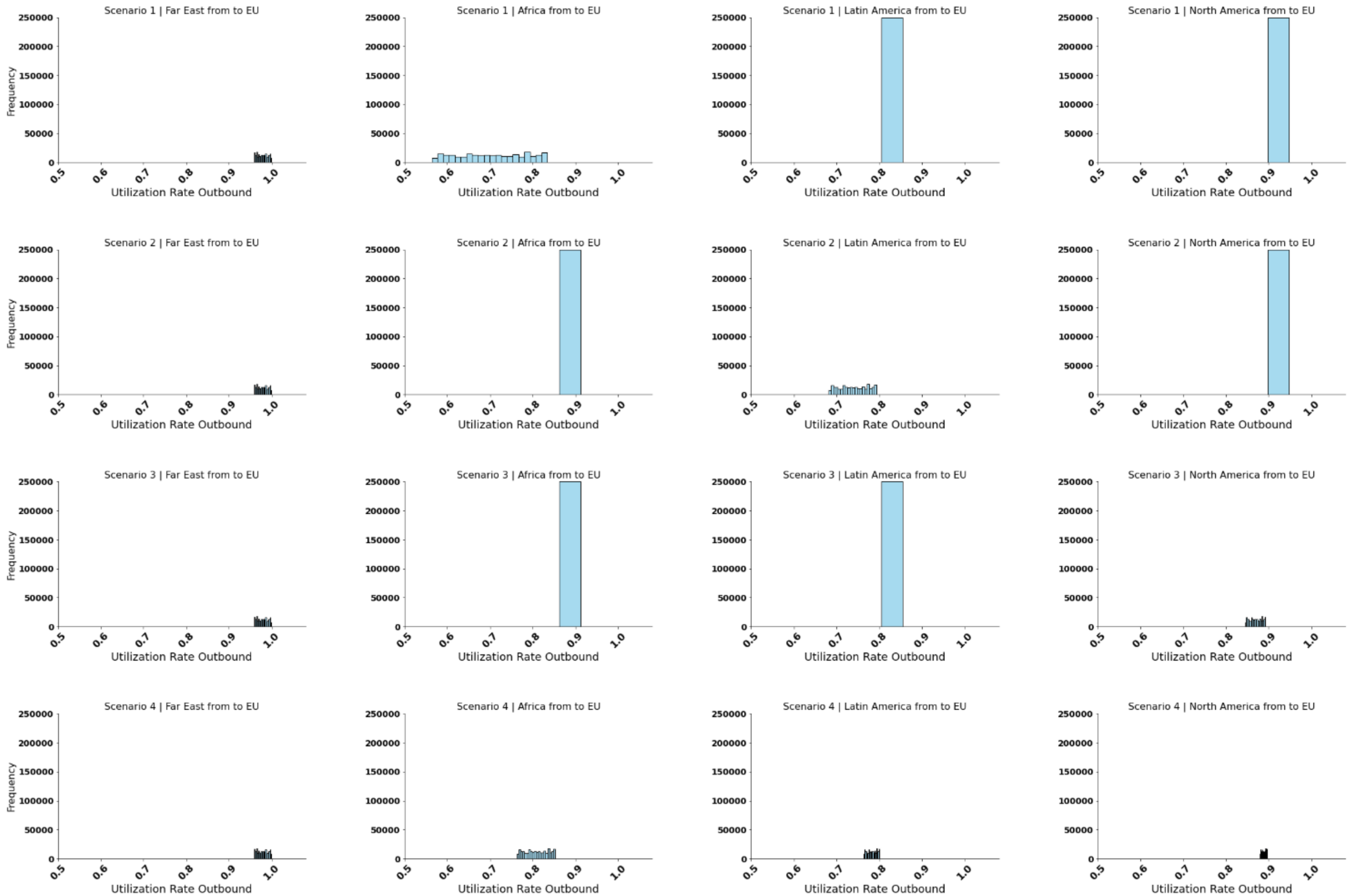


Figure 45 Distribution of Utilization Rate Outbound Across Regions and Scenarios (in a hundred percent)

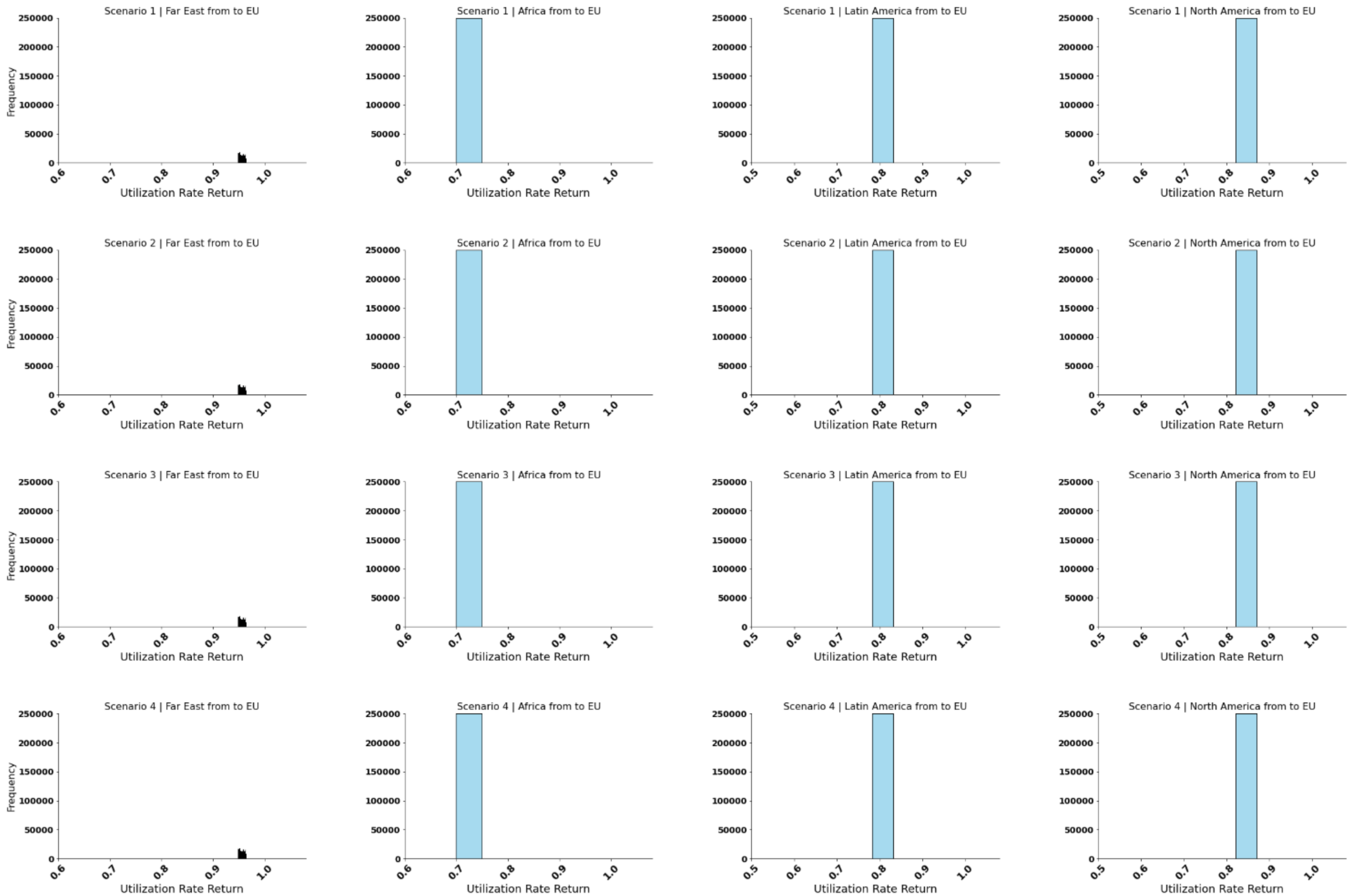


Figure 46 Distribution of Utilization Rate Return Across Regions and Scenarios (in Hundred Percent)

6.2.3 Analysis based on Heatmap Visualization

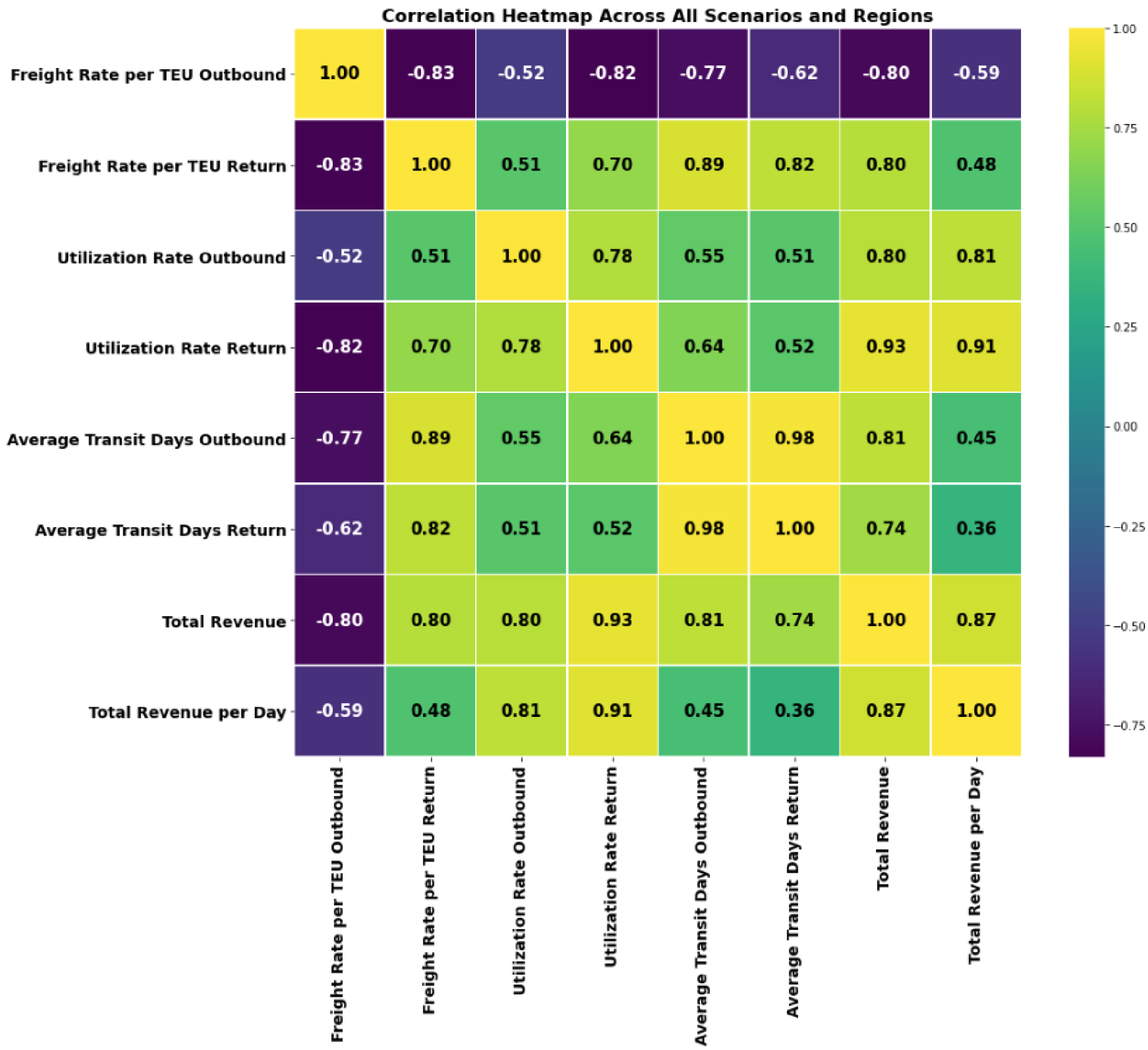


Figure 47 Correlation Heatmap Across All Scenarios and Regions

The analysis will first perform at the macro level, between all regions. In the case of curtailing full containers (**Figure 47**), return and outbound rates (purple, -0.83) highlighted a strong negative correlation, which means that an increase in return rates will decrease the outbound rates if we look at all scenarios and regions. Outbound rate overall gives a negative moderate correlation to outbound utilization rates (purple, -0.52), a strong negative correlation to return utilization rates (purple, -0.82), a strong negative correlation to outbound average transit days (purple, -0.77), a moderate negative correlation to return average transit days (purple, -0.62), a strong negative correlation to total revenue (purple, -0.80), and a moderate negative correlation to total revenue per day (purple, -0.59). In contrast, return freight rates show a moderate positive correlation with outbound utilization rates (green, 0.51), a strong positive correlation to return utilization rates (green, 0.70) utilization rates, a strong positive correlation to outbound (green, 0.89) and return (green, 0.82) average transit days, a strong positive correlation to total revenue (green, 0.80), and a moderate positive correlation to total revenue per day (green, 0.48).

Utilization rate outbound points out a strong positive correlation with return utilization rate (green, 0.78), a moderate positive correlation with outbound (green, 0.55) and return (green, 0.51) average transit days, a strong positive correlation with total revenue (green, 0.80) and total revenue per day (green, 0.81). Utilization rate return underlines a moderate positive correlation with outbound (green, 0.64) and return (green, 0.52) average transit days, a strong positive correlation with total revenue (green, 0.93) and total revenue per day (green, 0.91). Average transit outbound highlights a strong positive correlation with total revenue (green, 0.81) and a moderate positive correlation with total revenue per day (green, 0.45). Finally, average transit days return also highlights a strong positive correlation with total revenue (green, 0.74) and a moderate positive correlation with total revenue per day (green, 0.36).

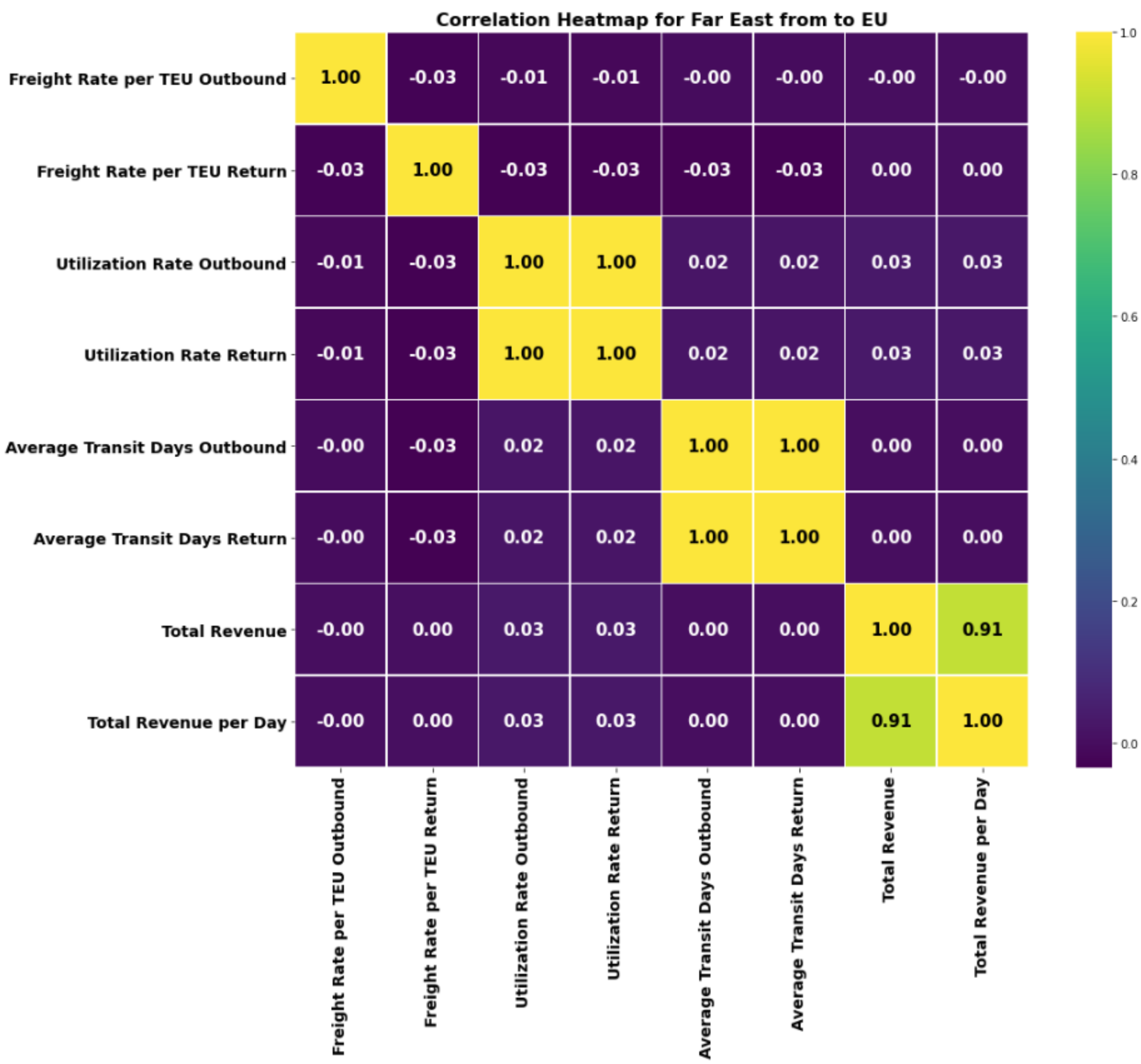


Figure 48 Correlation Heatmap for Far East from to EU

After analyzing the correlation in an overall manner, the study aims to do ***further analysis in a region-based manner to compare the result with the overall region result***. **Figure 48** emphasizes that in the case of trade between Far East and EU, return and outbound freight rates (purple, -0.03) show little to no correlation, suggesting minimal interdependence. Outbound freight rates exhibit little to no correlations with outbound utilization rates (purple, -0.01), return utilization rates (purple, -0.01), outbound average transit days (purple, -0.00), return average transit days (purple, -0.00), total revenue (purple, -0.00), and total revenue per day (purple, -0.00). Similarly, return freight rates show no significant correlation with outbound utilization rates (purple, -0.03), return utilization rates (purple, -0.03), outbound average transit days (purple, -0.03), return average transit days (purple, -0.03), total revenue (purple, 0.00), and total revenue per day (purple, 0.00).

Outbound utilization rates point out a strong positive correlation with return utilization rates (yellow, 1.00), and little to no correlation with outbound average transit days (purple, 0.02), return average transit days (purple, 0.02), total revenue (purple, 0.03), and total revenue per day (purple, 0.03). Return utilization rates also demonstrate strong positive correlations with outbound utilization rates (yellow, 1.00), and little to no correlation with outbound average transit days (purple, 0.02), return average transit days (purple, 0.02), total revenue (purple, 0.03), and total revenue per day (purple, 0.03). Outbound average transit days highlight strong positive correlations with return average transit days (yellow, 1.00) and negligible correlations with total revenue (purple, 0.00) and total revenue per day (purple, 0.00). Similarly, return average transit days show similar correlations with total revenue (purple, 0.00) and total revenue per day (purple, 0.00).

Figure 49 emphasizes that in the case of trade between Africa and EU, return and outbound freight rates (purple, -0.01) show little to no correlation, indicating that changes in one have no measurable impact on the other. Outbound freight rates exhibit little to no correlations with outbound utilization rates (purple, -0.07), outbound average transit days (purple, -0.01), return average transit days (purple, -0.01), total revenue (purple, -0.04), and total revenue per day (purple, -0.03). Similarly, return freight rates demonstrate no correlations with outbound utilization rates (purple, 0.01), outbound average transit days (purple, 0.03), return average transit days (purple, 0.03), total revenue (purple, 0.01), and total revenue per day (purple, 0.01).

Outbound utilization rates point out a moderate positive correlation with total revenue (green, 0.55) and total revenue per day (green, 0.49) while having little to no correlations with outbound average transit days (purple, -0.01) and return average transit days (purple, -0.01). Return utilization rates show a blank amount and no color in heatmaps due to no changes in return utilization in Alternative 2. Outbound average transit days highlight strong correlations with return average transit days (yellow, 1.00) but no correlations with total revenue (purple, -0.01) and total revenue per day (purple, -0.01). Similarly, return average transit days exhibit a perfect correlation with outbound transit days (yellow, 1.00) but no correlation with total revenue (purple, -0.01) and total revenue per day (purple, -0.01).

Figure 49 Correlation Heatmap for Africa from to EU

Figure 50 Correlation Heatmap for Latin America from to EU

Figure 50 highlight the trade between Latin America and EU that return and outbound freight rates (purple, 0.01) show little to no correlation, indicating no measurable interdependence between the two. Outbound freight rates exhibit little to no correlations with outbound utilization rates (purple, 0.02), outbound average transit days (purple, -0.03), return average transit days (purple, -0.03), total revenue (purple, 0.00), and total revenue per day (purple, 0.00). Similarly, return freight rates demonstrate little to no correlations with outbound utilization rates (purple, 0.01), outbound average transit days (purple, -0.01), return average transit days (purple, -0.01), total revenue (purple, 0.00), and total revenue per day (purple, 0.00).

Outbound utilization rates point out a weak positive correlation with total revenue (purple, 0.18) and total revenue per day (purple, 0.13) while showing little to no correlations with outbound average transit days (purple, 0.00) and return average transit days (purple, 0.00). Return utilization rates show a blank amount and no color in heatmaps due to no changes in return utilization in Alternative 2. Average transit days outbound exhibit strong correlations with return average transit days (yellow, 1.00) but negligible correlations with total revenue (purple, 0.00) and total revenue per day (purple, -0.00). Similarly, return average transit days show the same correlation patterns with outbound transit days (yellow, 1.00) and negligible with total revenue (purple, 0.00) and total revenue per day (purple, -0.00).

Figure 51 Correlation Heatmap for North America from to EU

Figure 51 highlight the trade between North America and EU that return and outbound freight rates (purple, 0.00) show a little to no correlation between the two parameters. Outbound freight rates negligible correlations with outbound utilization rates (purple, -0.03), outbound average transit days (purple, -0.01), return average transit days (purple, -0.01), total revenue (purple, -0.00), and total revenue per day (purple, -0.00). Similarly, return freight rates show negligible correlations with outbound utilization rates (purple, -0.00), outbound average transit days (purple, -0.03), return average transit days (purple, -0.03), total revenue (purple, -0.00), and total revenue per day (purple, -0.00).

Outbound utilization rates highlight weak positive correlations with total revenue (purple, 0.11) and total revenue per day (purple, 0.10) while showing negligible correlations with return (purple, 0.03) and outbound average transit days (purple, 0.03). Return utilization rates show a blank amount and no color in heatmaps due to no changes in return utilization in Alternative 2.

Average transit days outbound exhibit strong correlations with return average transit days (yellow, 1.00), but negligible correlations with total revenue (purple, 0.00) and total revenue per day (purple, -0.00). Similarly, return average transit days show the same correlation patterns as outbound transit days (yellow, 1.00) and are negligible with total revenue (purple, 0.00) and total revenue per day (purple, 0.00).

Previous heatmaps have not included additional empties in the parameter. The study will identify the impact of additional empties from curtailing from other regions to be repositioned in the Far East within each region. Far East will be first analyzed, and **Figure 52** depicts that return and outbound freight rates (purple, -0.03) show little to no correlation, suggesting minimal interdependence between the two. Outbound freight rates exhibit little to no correlations with outbound utilization rates (purple, -0.01), additional empties outbound (purple, -0.01), additional empties return (purple, -0.01), return utilization rates (purple, -0.01), outbound average transit days (blue, -0.00), return average transit days (purple, -0.00), total revenue (purple, -0.00), and total revenue per day (purple, -0.00). Similarly, return freight rates show little to no correlations with outbound utilization rates (purple, -0.03), additional empties outbound (purple, -0.03), additional empties return (purple, -0.03), return utilization rates (purple, -0.03), outbound average transit days (purple, -0.03), return average transit days (purple, -0.03), total revenue (purple, 0.00), and total revenue per day (purple, 0.00).

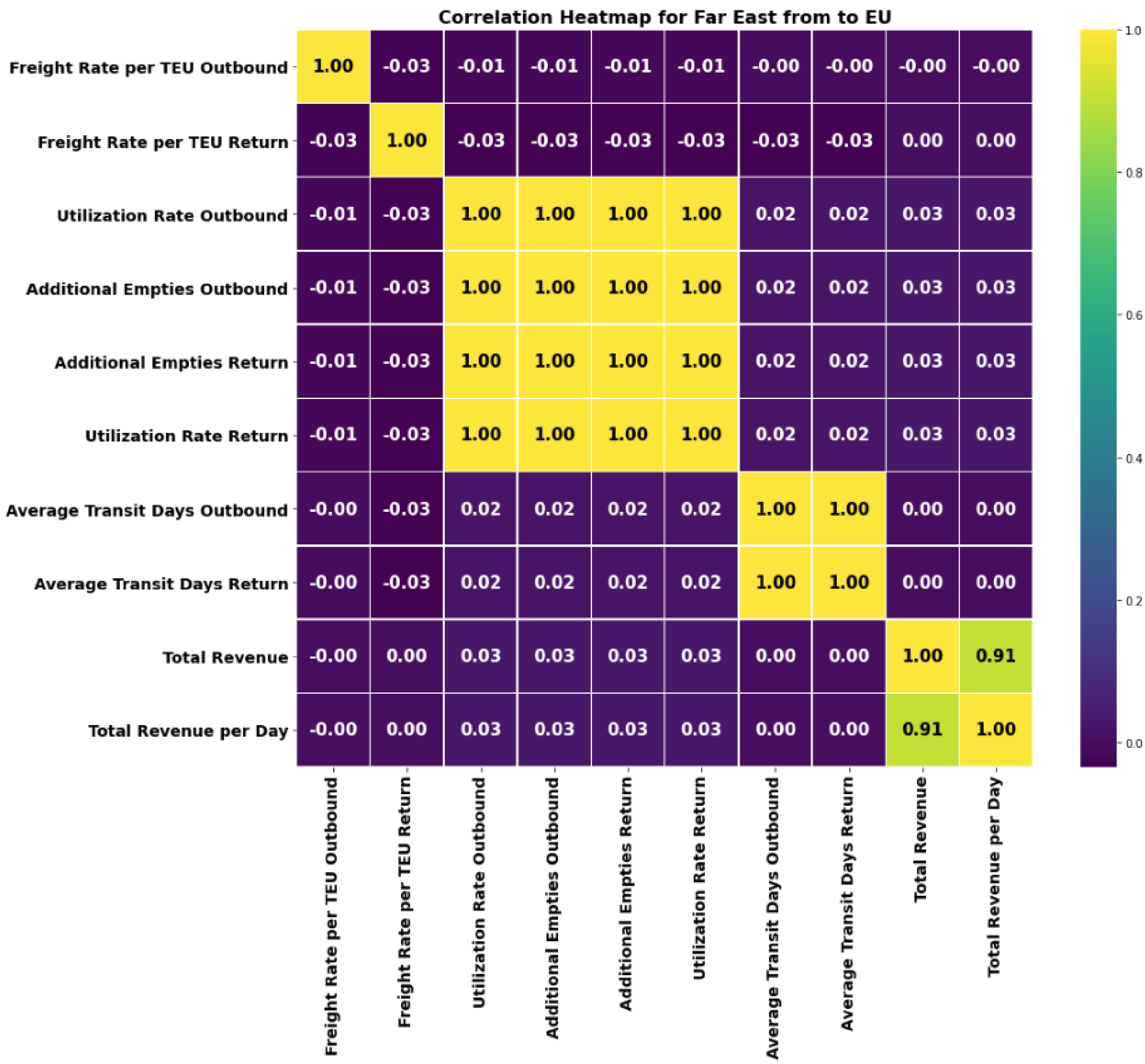


Figure 52 Correlation Heatmap for Far East from to EU related to Additional Empties

Outbound utilization rates exhibit a strong correlation with additional empties outbound (yellow, 1.00), additional empties return (yellow, 1.00), and return utilization rates (yellow, 1.00), alongside little to no correlations with outbound average transit days (purple, 0.02), return average transit days (purple, 0.02), total revenue (purple, 0.03), and total revenue per day (purple, 0.03). Additional empties outbound and return both show strong positive correlations with one another (yellow, 1.00) and with utilization rates outbound and return (yellow, 1.00) while exhibiting little to no correlations with outbound and return average transit days (purple, 0.02), total revenue (purple, 0.03), and total revenue per day (purple, 0.03).

Average transit days outbound highlight strong correlations with return average transit days (yellow, 1.00) but little to no correlations with total revenue (purple, 0.00) and total revenue per day (purple, 0.00). Similarly, return average transit days exhibit the same correlation patterns as outbound transit days (dark red, 1.00) and are negligible with total revenue (purple, 0.00) and total revenue per day (purple, 0.00).

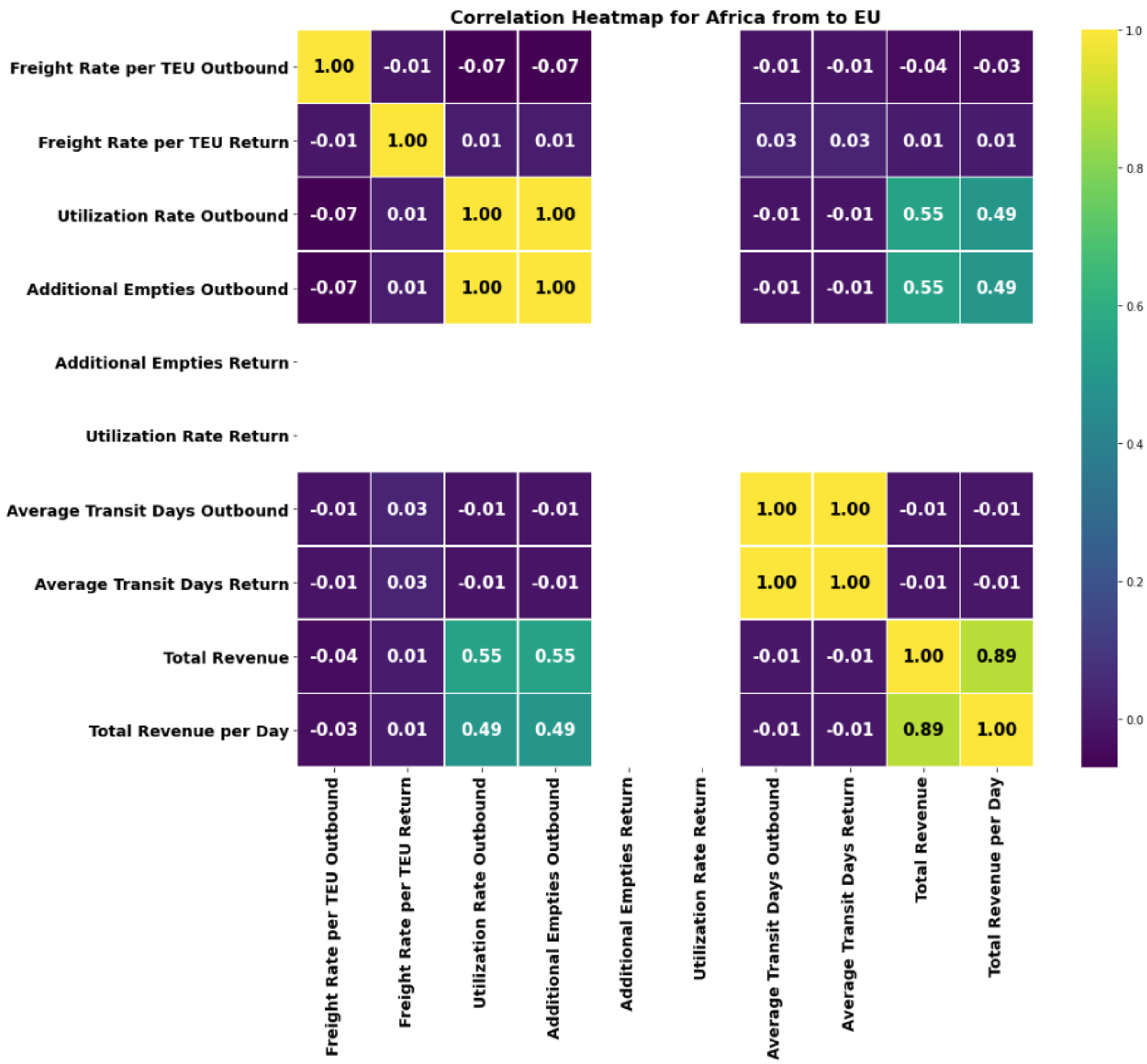


Figure 53 Correlation Heatmap for Africa from to EU related to Additional Empties

Figure 53 depicts the trade within Africa and the EU with return and outbound freight rates (purple, -0.01) showing little to no measurable correlation, indicating minimal interdependence between the two. Return additional empties and utilization rate are not applicable since no changes happen to both parameters due to no changing demand in the return journey assumption. Outbound freight rates exhibit little to no correlations with outbound utilization rates (purple, -0.07), additional empties outbound (purple, -0.07), outbound average transit days (purple, -0.01), return average transit days (purple, -0.01), total revenue (purple, -0.04), and total revenue per day (purple, -0.03). Similarly, return freight rates demonstrate no correlations with outbound utilization rates (purple, 0.01), additional empties outbound (purple, 0.01), outbound average transit days (purple, 0.03), return average transit days (purple, 0.03), total revenue (purple, 0.01), and total revenue per day (purple, 0.01).

Outbound utilization rates highlight a strong correlation with additional empties outbound (yellow, 1.00), little to no correlation with average transit days (purple, -0.01), return average transit days (purple, -0.01), as well as moderate positive correlations with total revenue (green, 0.55) and total revenue per day (green, 0.49). Additional empties outbound shows strong correlations with outbound utilization rates (yellow, 1.00) while demonstrating little to no correlations with average transit days outbound (purple, -0.01) and return (purple, -0.01), and a moderate positive correlation with total revenue (green, 0.55) and total revenue per day (green, 0.49).

Average transit days outbound exhibit strong positive correlations with return average transit days (yellow, 1.00) but negligible correlations with total revenue (purple, -0.01) and total revenue per day (purple, -0.01). Similarly, average transit days follow the same trend, perfectly correlating with outbound transit days (yellow, 1.00) and negligibly correlating with total revenue (purple, -0.01) and total revenue per day (purple, -0.01).

Figure 54 Correlation Heatmap for Latin America from to EU related to Additional Empties

Figure 54 illustrate trade within Latin America and the EU with return and outbound freight rates (purple, 0.01) show no significant correlation, indicating minimal interdependence. Return additional empties and utilization rate are not applicable since no changes happen to both parameters due to no changing demand in the return journey assumption. Outbound freight rates exhibit little to no correlations with outbound utilization rates (purple, -0.01), additional empties outbound (purple, -0.01), outbound average transit days (purple, -0.03), return average transit days (purple, -0.03), total revenue (purple, 0.00), and total revenue per day (purple, 0.00). Similarly, return freight rates demonstrate little to no correlations with outbound utilization rates (purple, 0.01), additional empties outbound (purple, 0.01), outbound average transit days (purple, -0.01), return average transit days (purple, -0.01), total revenue (purple, 0.00), and total revenue per day (purple, 0.00).

Outbound utilization rates highlight a strong correlation with additional empties outbound (yellow, 1.00), as well as weak correlations with total revenue (purple, 0.18) and total revenue per day (purple, 0.13). Additional empties outbound show strong correlations with outbound utilization rates (yellow, 1.00) while exhibiting weak correlations with revenue (purple, 0.18), and total revenue per day (purple, 0.13).

Average transit days outbound exhibit strong correlations with return average transit days (yellow, 1.00) but little to no correlations with total revenue (purple, 0.00) and total revenue per day (purple, -0.00). Similarly, return average transit days follow the same trend, strongly correlating with outbound transit days (yellow, 1.00) and negligibly correlating with total revenue (purple, 0.00) and total revenue per day (purple, 0.01).

Figure 55 illustrates the trade between North America and the EU with return and outbound freight rates (purple, 0.00), showing no correlation, indicating no interdependency. Return additional empties and utilization rate are not applicable since no changes happen to both parameters due to no changing demand in the return journey assumption. Outbound freight rates exhibit little to no correlations with outbound utilization rates (purple, -0.03), additional empties outbound (purple, -0.03), outbound average transit days (purple, -0.01), return average transit days (purple, -0.01), total revenue (purple, 0.00), and total revenue per day (purple, 0.00). Similarly, return freight rates demonstrate little to no correlations with outbound utilization rates (purple, -0.00), additional empties outbound (purple, -0.00), outbound average transit days (purple, -0.03), return average transit days (purple, -0.03), total revenue (purple, -0.00), and total revenue per day (purple, -0.00).

Outbound utilization rates highlight a strong positive correlation with additional empties outbound (yellow, 1.00), weak positive correlations with total revenue (purple, 0.11) and total revenue per day (purple, 0.10), as well as little to no correlation to average transit days outbound (purple, 0.03) and return (purple, 0.03). Additional empties outbound show strong correlations with outbound utilization rates (yellow, 1.00) while exhibiting little to no correlations with average transit days outbound (purple, 0.03) and return (purple, 0.03), and a weak positive correlation with total revenue (purple, 0.10 and total revenue per day (purple, 0.09).

Average transit days outbound exhibit strong positive correlations with return average transit days (yellow, 1.00) but negligible correlations with total revenue (purple, 0.00) and total revenue per day (purple, 0.00). Similarly, average transit days return follows the same trend, strongly correlating with outbound transit days (yellow, 1.00) and negligibly correlating with total revenue (purple, 0.00) and total revenue per day (purple, 0.00).

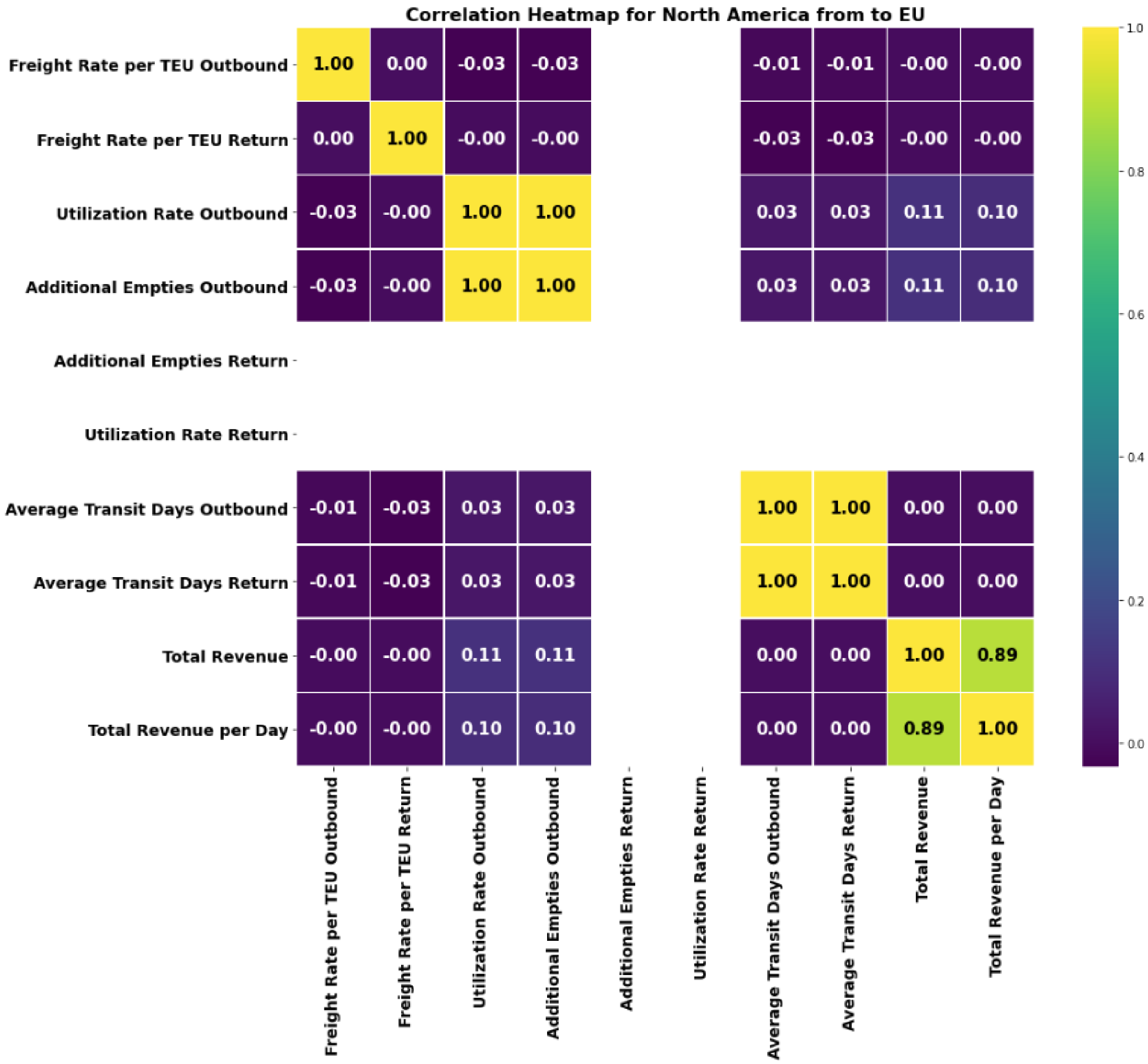


Figure 55 Correlation Heatmap for North America from to EU related to Additional Empties

6.2.3 Impact of Curtailment to Revenue per Region

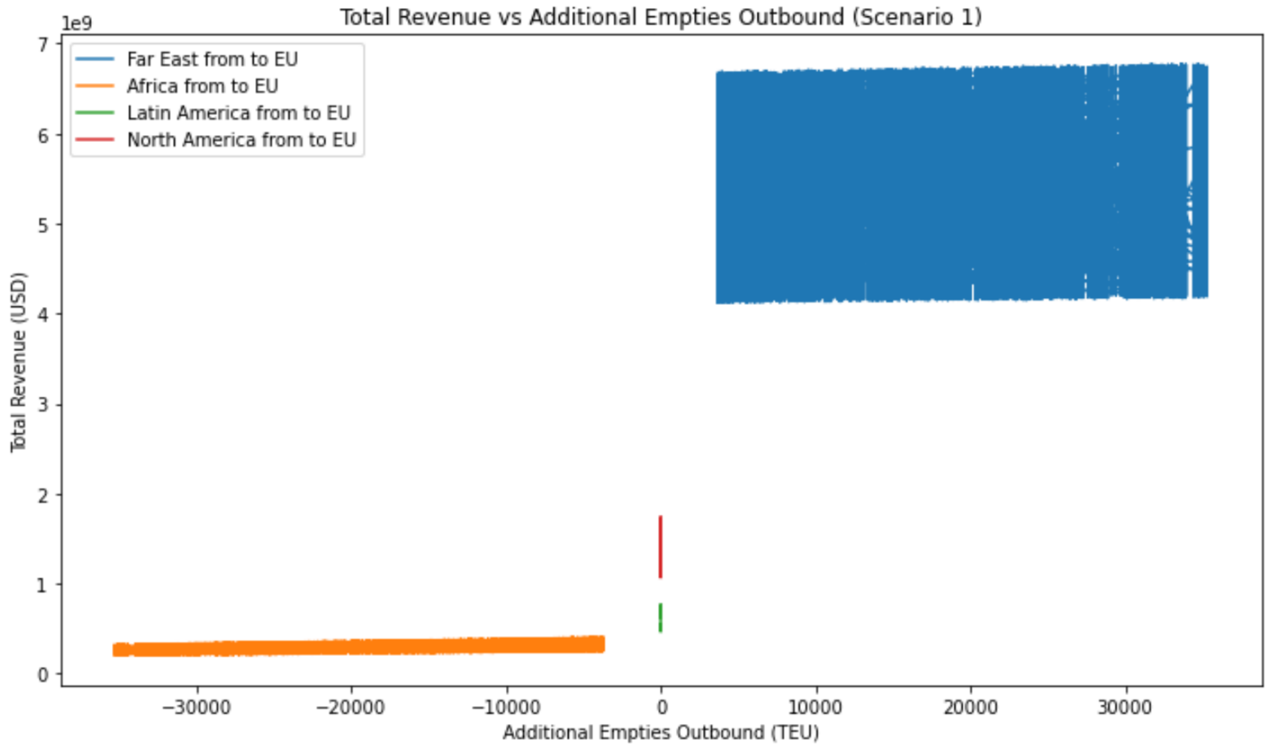


Figure 56 Total Revenue vs Additional Empties Outbound in Scenario 1

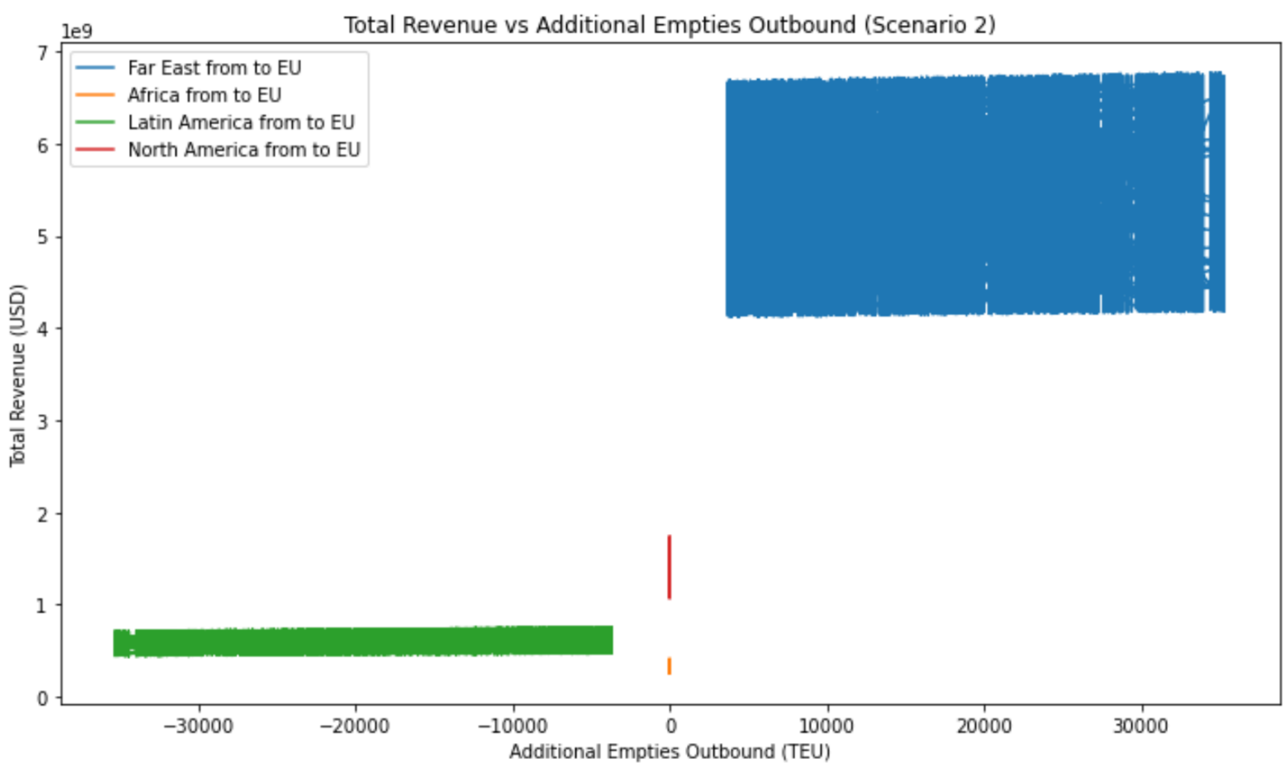


Figure 57 Total Revenue vs Additional Empties Outbound in Scenario 2

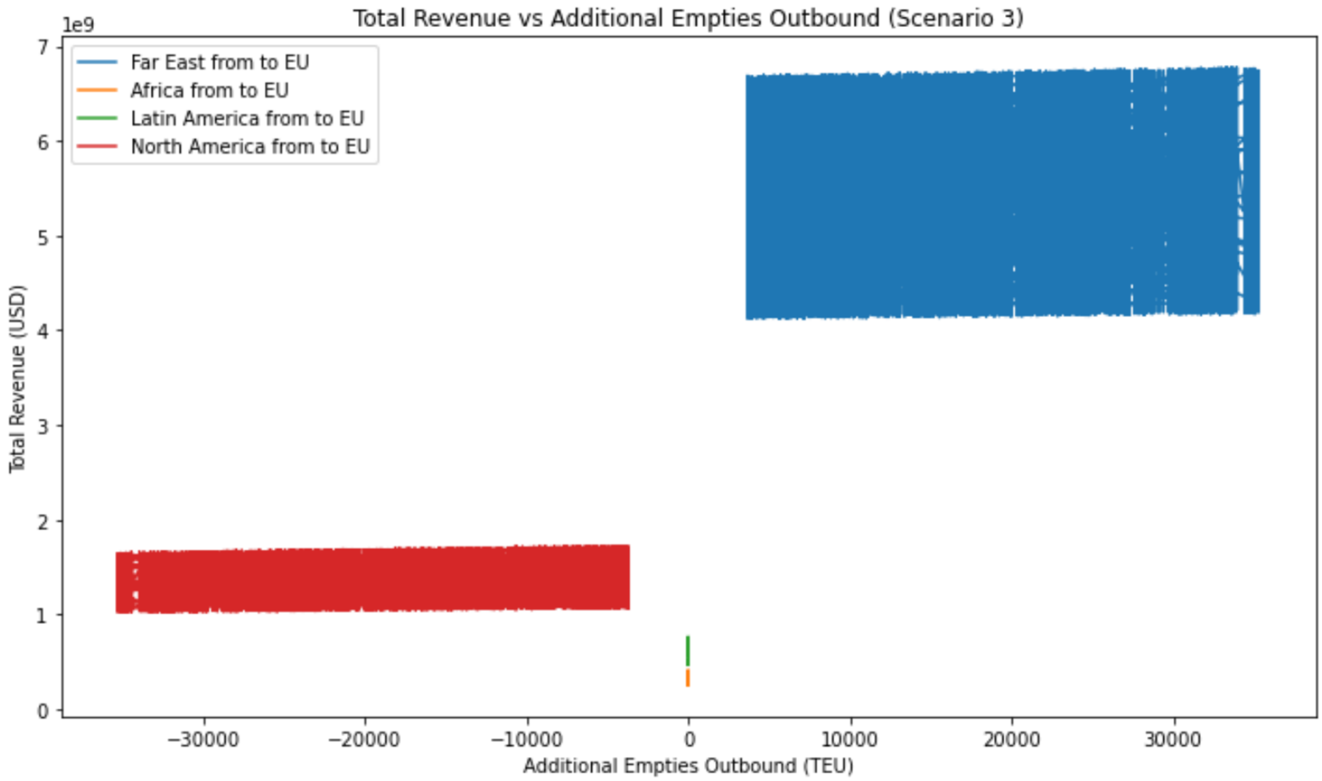


Figure 58 Total Revenue vs Additional Empties Outbound in Scenario 3

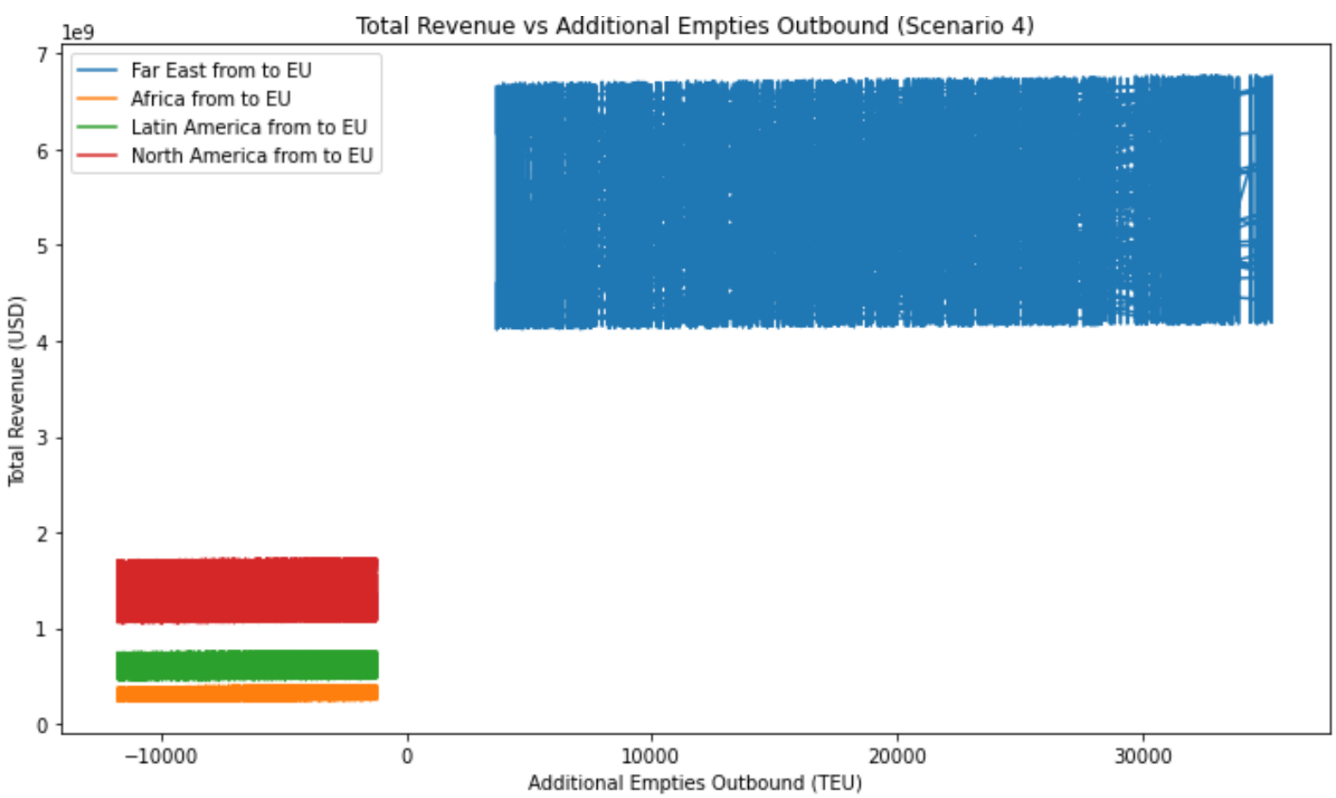


Figure 59 Total Revenue vs Additional Empties Outbound in Scenario 4

The above result on **Figure 56**, **Figure 57**, **Figure 58**, and **Figure 59** show consistent result with the data explained in the previous histogram in Section 0 **6.2.1 Analysis based on Histogram Visualization**. The curtailment of outbound trade does not significantly affect the total revenue. The diagram shows that regardless of the amount of containers curtailed from the outbound journey, it can still achieve a similar range of total revenue

6.2.4 Seasonality Implications on Alternative 2

This study assesses the impact of seasonality when performing prioritizing of allocating the empty containers to deficit region. The concept of executing the simulation is still the same when doing it without seasonality. However, the simulation is performed in monthly fashion to address the seasonal pattern in each month. The total revenue obtained monthly will then be aggregated to get the full year total revenue.

The simulation results indicate the average total revenues for each region per scenario as follows:

1. **Scenario 1**, a) **Far East**, with an average of 5.503 billion dollars; b) **Africa**, with an average of 0.323 billion dollars; c) **Latin America**, with an average of 0.594 billion dollars; and d) **North America**, with an average of 1.41 billion dollars. The **average total revenue across regions** is **7.83 billion dollars**, calculated as the sum of the average total revenue from every region.
2. **Scenario 2**, a) **Far East**, with an average of 5.517 billion dollars; b) **Africa**, with an average of 0.341 billion dollars; c) **Latin America**, with an average of 0.587 billion dollars; and d) **North America**, with an average of 1.408 billion dollars. The **average total revenue across regions** is **7.85 billion dollars**, calculated as the sum of the average total revenue from every region.
3. **Scenario 3**, a) **Far East**, with an average of 5.498 billion dollars; b) **Africa**, with an average of 0.341 billion dollars; c) **Latin America**, with an average of 0.596 billion dollars; and d) **North America**, with an average of 1.394 billion dollars. The **average total revenue across regions** is **7.82 billion dollars**, calculated as the sum of the average total revenue from every region.
4. **Scenario 4**, a) **Far East**, with an average of 5.216 billion dollars; b) **Africa**, with an average of 0.335 billion dollars; c) **Latin America**, with an average of 0.592 billion dollars; and d) **North America**, with an average of 1.405 billion dollars. The **average total revenue across regions** is **7.55 billion dollars**, calculated as the sum of the average total revenue from every region.

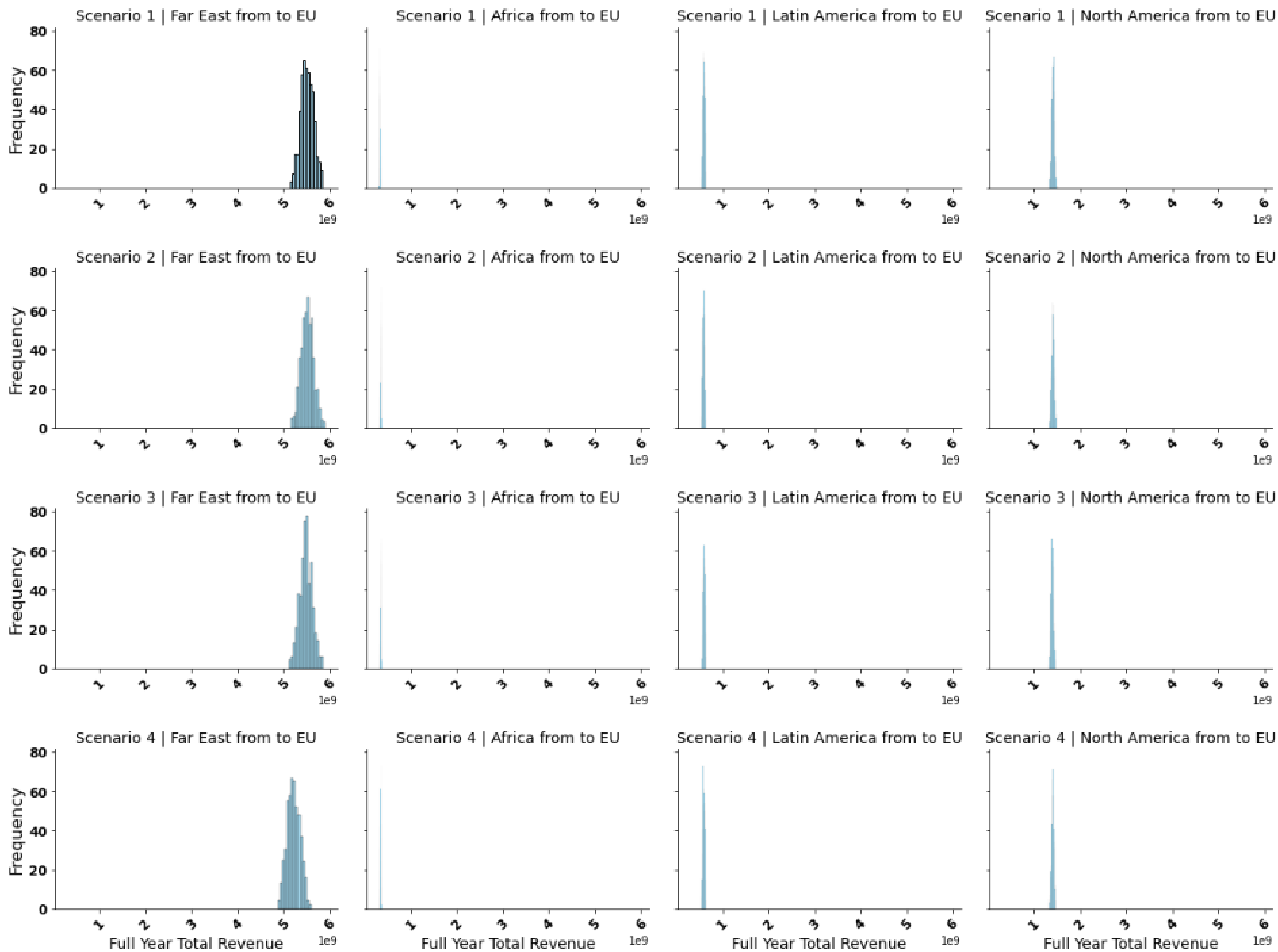


Figure 60 Distribution of Total Revenue Across Region (in Billion Dollars)

Alternative 2 without seasonality depicted that the range of total revenue was around 1 to 6 billion dollars. In the context of seasonality, the total revenue of **Far east** still falls within the range of without seasonality, amounting to around **5 to 6 billion dollars**. However, the difference falls in the range and distribution of the total revenue. This analysis shows that the range becomes smaller and located near the maximum value. The same applies to **Africa**, **Latin** and **North America**, the total revenue falls near the maximum range but still within the range of revenue when analyzing it without seasonality. The detail of maximum and minimal value of total revenue when accounting the seasonality is represented in Appendix L. In addition, the distribution in Far East and North America are more skewed compared to when there is no seasonality showing high variability due to the seasonality effect. In contrast, Africa and Latin America show no significant difference in the distribution pattern whether with or without seasonality.

Currently, Maersk's vessels operate within consistent capacity, making adjusting deliveries drastically from month to month impractical. Maersk executes the chosen strategy once it becomes appropriate, steadily year-round, minimizing the impact of seasonal variations. While localized peaks or seasonal trends may occur in specific countries, these are too granular to influence the broader analysis. Demand peaks necessitate advance planning for container supply due to fixed weekly vessel capacity. This requires a consistent, year-round pre-supply strategy to effectively meet peak demand. Fast steaming is identified as a potential approach to address peak demand by increasing shipment frequency during high-demand periods, provided customers are willing to pay a premium. This approach is occasionally implemented before peak seasons to optimize timing. In addition, most of Maersk's customers are contractual. Therefore, the focus remains on maintaining a stable and efficient operational approach, rendering seasonality a secondary consideration at the macro level because the capacity between trades is relatively fixed, with limited flexibility for significant monthly fluctuations.

The shipping firm and these long-term customers negotiate the freight rate of the long-term contract shipping demand, and the volume of this demand is relatively consistent between the two parties. Consequently, the profit derived from long-term contract demand is typically fixed (Wang & Meng, 2021).

This statement is supported with the analysis result for seasonality. The result shows a more stable revenue due to the smaller range. The skewed distributions show that there are some peak seasons where the demand is higher than normal. Long-term contracts make it possible to predict earlier when the demand is possibly higher or lower. Hence, resulting in more stable and less range on the total revenue.

6.2.5 Findings on Alternative 2 Analysis

Histogram analysis on Alternative 2 without seasonality shows that total revenue per day from return and outbound trade in Africa changes significantly when curtailed from Africa, indicating higher variability compared to Alternative 1. The range of total revenue per day remains unaffected when curtailed from other regions. In contrast, Latin and North America show slightly different ranges and distributions when full containers are curtailed from their regions. In context of total revenue, Far East and North America contribute the highest total revenue overall, but with minimal variability compared to Alternative 1. Africa and Latin America show slight changes in their lower range values when curtailed from their region, while Africa and Latin America show no significant impact on overall total revenue. The potential loss of revenue from curtailing trade does not substantially impact on any of the regions. In the Far East, where additional revenues could be expected due to the availability of extra empty containers, the effect is minimal. This is attributed to the proportion of repositioned empty containers being negligible compared to the volume of full containers (0.0000507 - 0.000562%). Regarding utilization rates, the goal of achieving 100% utilization on outbound journeys from Europe to the Far East is successfully achieved.

Histogram analysis on Alternative 2 with seasonality shows that total revenue falls within the maximum range without seasonality, with skewed distributions in Far East and North America. In contrast, Africa and Latin America show no significant difference whether there is seasonal effect or not. Seasonality results show more stable revenue due to smaller range, with skewed distributions indicating peak seasons with higher demand. Long-term contracts allow for earlier predictions, resulting in more stable total revenue.

TABLE 13 demonstrated the summary of comparison between Alternative 1, Alternative 2 without seasonality and Alternative 2 with seasonality.

Heat Map analysis on Alternative 2 (without seasonality) concluded that at the ***macro level***, outbound and return rates have a significant impact on all parameters, such as return and outbound utilization rates, outbound and return average transit days, total revenue, and total revenue per day. Conversely, there is a negative correlation between outbound and return rates. It is important to manage the outbound rates since it has a negative impact on utilization rates, outbound and return average transit days, and total revenue per day. The increase in outbound rate could decrease the six parameters at a macro level. Furthermore, finding the balance between outbound and return rates is essential to optimize the overall revenue across regions. Additionally, total revenue and total revenue per day are also impacted by utilization rates outbound and return, as well as average transit day outbound and return. Hence, optimizing both outbound and return utilization rates and average transit days is significant in achieving maximum revenue.

Additionally, further analysis in a **region-based** shows different result with macro level***.*** In Far East, there is a perfect correlation between outbound and return utilization rates. An increase in outbound utilization rates should also increase the return utilization rate. Furthermore, there is a perfect correlation between the average outbound transit days and the average return transit days. Therefore, utilization rates outbound and return, average transit days outbound and return are the significant operational parameters in Far East. Maintaining the balance between both outbound and return utilization rates and average transit days is essential in Far East.

Africa shows that average transit days outbound are perfectly correlated with return transit days. It is important to maintain the optimum amount of average transit days outbound and return in Africa. Utilization rate outbound also plays an important role in total revenue and total revenue per day due to its moderate correlation. It is essential to manage high outbound utilization rates for trade in Africa to achieve a higher financial impact.

In Latin America, it shows that the changes in average days outbound will affect the average days return. Hence, maintaining the optimum average transit days outbound and return is important in Latin America, as well as the outbound utilization rate. Lastly, North America demonstrates similar results with Latin America, where average transit days return and outbound, as well as outbound utilization rate, play a significant role in the operational level.

When accounting for the impact of additional empties in the heatmap analysis, Far East show the same result as the previous analysis when ignoring the additional empties. The difference is only in the correlation of additional empty outbound, where it is a significant factor in both outbound and return utilization rates. Thus, utilization rates outbound and return, average transit days outbound and return, and additional empties outbound are the significant operational parameters in Far East. Maintaining the balance between both outbound and return utilization rates and average transit days is essential in Far East.

In Africa, the result is the same with the analysis while disregarding the additional empties outbound. Additional insight gain from this analysis is outbound utilization rates are perfectly correlated with additional empties outbound, while additional empties outbound itself has a large impact on total revenue and total revenue per day. Consequently, any changes in the number of full containers curtailed will affect the outbound utilization rate, total revenue, and total revenue per day. To maintain revenue in Africa, it is preferable to maintain a high outbound utilization rate since it will influence revenue outcomes.

In Latin America, the number of full containers curtailed from Latin America will influence the outbound utilization rate outcome. However, there is a weak correlation between additional empties outbound with total revenue and total revenue per day. Hence, the changes in outbound utilization rate due to the curtailed full container will not significantly influence the revenue outcomes. While the other result remains the same when disregarding the additional empties in the analysis.

Lastly, North America demonstrates similar results with Latin America, where additional empty outbound does have a perfect correlation with outbound utilization rate. However, the analysis identified a weak correlation between additional empty outbound and total revenue and total revenue per day. The other analysis stays unchanged when conducted without the incorporation of additional empty.

Table 13 Comparison Between Alternative 1 And 2

Region	Key Parameters	Alternative 1	Alternative 2 – Scenario 1	Alternative 2 – Scenario 2	Alternative 2 – Scenario 3	Alternative 2 – Scenario 4
Far East from to EU	Total Revenue	4.1 to 6.7 billion	4.1 to 6.72 billion	4.1 to 6.75 billion	4.1 to 6.73 billion	4.1 to 6.72 billion
	Total Revenue per Day	60 million to 120 million	64.6 to 132 million	65 million to 132 million	63 million to 131 million	64.4 million to 132 million
	Utilization Rate Outbound		96% to 100%	96% to 100%		
	Utilization Rate Return		95% to 96%	95% to 96%		
	Total Revenue (Seasonality)		5.08 to 5.91 billion	5.1 to 5.9 billion	5.2 to 5.9 billion	5.1 to 6 billion
	Total Revenue per Day (Seasonality)		89 to 106 million	89 to 106 million	90 to 105 million	89 to 105 million
Africa from to EU	Total Revenue	0.26 to 0.4 billion	0.2 to 0.4 billion	0.25 to 0.4 billion	0.25 to 0.4 billion	0.24 to 0.4 billion
	Total Revenue per Day	6 to 12 million	4.72 and 12 million dollars	6 to 12 million	6 to 12 million	5.8 to 12
	Utilization Rate Outbound		56% to 83%	86%	86%	86%
	Utilization Rate Return		70%	70%	70%	70%
	Total Revenue (Seasonality)		0.31 to 0.34 billion	0.32 to 0.36 billion	0.32 to 0.36 billion	0.32 to 0.35 billion
	Total Revenue per Day (Seasonality)		8.1 to 9.4 million dollars	8.5 to 9.9 million	8.5 to 9.9 million	8.4 to 9.8 million
Latin America from to EU	Total Revenue	0.47 to 0.75 billion	0.47 to 0.76 billion	0.44 to 0.76 billion	0.47 to 0.76 billion	0.46 to 0.76 billion
	Total Revenue per Day	16 to 28 million	15 to 30 million	15 to 30 million	15 to 30 million	15 to 30 million
	Utilization Rate Outbound		80%	68% to 79%	80%	80%
	Utilization Rate Return		78%	78%	78%	78%
	Total Revenue (Seasonality)		0.54 to 0.64 billion	0.54 to 0.63 billion	0.53 to 0.64 billion	0.55 to 0.64 billion

Region	Key Parameters	Alternative 1	Alternative 2 – Scenario 1	Alternative 2 – Scenario 2	Alternative 2 – Scenario 3	Alternative 2 – Scenario 4
	Total Revenue per Day (Seasonality)		18.9 to 23.5 million	19 to 23 million	65.9 to 76 million	19 to 24 million
North America from to EU	Total Revenue	1.1 to 1.7 billion	1.1 to 1.7 billion	1.1 to 1.7 billion	1 to 1.7 billion	1 to 1.7 billion
	Total Revenue per Day	50 million to 93 million	49 to 98 million	49 to 98 million	47 to 97 million	48 to 97 million
	Utilization Rate Outbound		90%	90%	90%	88% to 90%
	Utilization Rate Return		82%	82%	82%	82%
	Total Revenue (Seasonality)		1.3 to 1.5 billion	1.3 to 1.49 billion	1.3 to 1.47 billion	1.3 to 1.49 billion
	Total Revenue per Day (Seasonality)		65.9 to 76.9 million	65 to 77.7 million	66 to 76 million	65 to 76 million

6.4. Sub-Conclusion

Histogram analysis shows that in **Alternative 1**, the **average total revenue** across European regions is **7.76 billion dollars**, with Africa, Latin America, and North America having skewed distributions. North America tends to have total revenue between 1 and 2, while Latin America and Africa are clustered in one area below zero. The Far East has a broader revenue range, suggesting greater potential for larger revenue. While **Alternative 2, with no seasonality**, shows that total revenue per day from return and outbound trade in Africa changes significantly when curtailed from Africa, indicating higher variability compared to Alternative 1. In the Far East, the potential loss of revenue from curtailing trade does not substantially impact any of the regions. Seasonality results show more stable revenue due to the smaller range but still falls withing the range of no seasonal effect, with skewed distributions indicating peak seasons with higher demand.

Heat map analysis in **Alternative 1** shows that changes in return freight rate influenced average transit days outbound and returns, total revenue, and total revenue per day in a positive direction, while outbound rate negatively influences the revenue outcome. Deeper analysis of region-based results shows varied insights into the parameters. In the Far East region, high return rates generate high revenue outcomes, while high average transit time return decreases total revenue per day. In Africa, outbound and return rates affect total revenue and total revenue per day, but outbound rates have a higher degree of influence on revenue outcomes. In Latin America, total revenue and total revenue per day are highly affected by return and outbound rates, and average transit days return negatively impacting total revenue per day. North America's revenue drivers are outbound journeys, with high outbound rates and low average transit days influencing total revenue. Maintaining high outbound rates and low transit days can improve revenue outcomes.

While **Alternative 2** shows that outbound and return rates significantly impact all parameters, including return and outbound utilization rates, outbound and return average transit days, total revenue, and total revenue per day. A negative correlation exists between outbound and return rates, making it crucial to manage them to optimize overall revenue across regions. Additionally, it is important to maintain outbound, return utilization rate, and average transit days (outbound and return) since those are significant in achieving maximum revenue. In Far East, there is a perfect correlation between outbound and return utilization rates; and average outbound transit days, and average return transit days. In Africa, average transit days outbound are perfectly correlated with return transit days. In addition, total revenue (and total revenue per day) is influenced by outbound utilization rate, making it essential to maintain high outbound utilization rates for trade. In Latin America, changes in average days outbound affect average days return, making it crucial to maintain the optimum average transit days outbound and return. North America also demonstrates similar results, with average transit days return and outbound, as well as outbound utilization rate, playing significant roles in operational levels. The analysis suggests that maintaining a balance between outbound and return utilization rates, average transit days, and additional empty outbound is essential for achieving maximum revenue across regions. The heatmap analysis when accounting for additional empties shows that there is a significant impact between additional empties on outbound and return utilization rates in Far East. However, the correlation between additional empty outbound and total revenue is significant in Africa. In Africa, maintaining a balance between outbound and return utilization rates and average transit days is crucial since those will affect the total revenue. In Latin America, the number of full containers curtailed affects outbound utilization rate, but there is a weak correlation between additional empties outbound and total revenue. North America also shows a perfect correlation with the outbound utilization rate, but a weak correlation with total revenue. Furthermore, the Far East and North America exhibit distinct drivers of revenue, which diverge from the patterns observed in Africa and Latin America in the case of curtailing. These regional differences likely explain why the aggregated results at the macro level deviate from the outcomes observed at the micro level for specific regions. Aggregation reveals the complex, region-specific elements affecting income, highlighting the necessity of examining each region separately to comprehend the distinct determinants of revenue and performance.

Table 14 Summary of Average Total Revenue Across Regions

Alternatives and Scenarios	Average Total Revenue Across Regions (billion dollars)	Standard Deviation of Total Revenue (billion dollars)	Average Total Revenue Across Region with seasonality (billion dollars)	Standard Deviation of Total Revenue Across Region with seasonality (billion dollars)
Alternative 1	7.76	0.75		
Alternative 2 – Scenario 1 (Africa)	7.71	0.75	7.83	0.14
Alternative 2 – Scenario 2 (Latin America)	7.75	0.75	7.85	0.14
Alternative 2 – Scenario 3 (North America)	7.72	0.75	7.82	0.14
Alternative 2 – Scenario 4 (combination of the three)	7.73	0.75	7.55	0.14

In conclusion, from the perspective of total overall revenue, Alternative 1 generally yields higher total average revenue by a slight difference. When examining Alternative 2 specifically, each scenario demonstrates similar results, with a range between 7.71 and 7.75 billion dollars and a consistent standard deviation of 0.75 billion dollars. The curtailment of Latin America appears slightly more advantageous compared to other regions. This aligns with the histogram analysis, which indicates that the revenue range for Latin America remains largely unaffected despite the curtailment. Aligned with the histogram and heat map analysis, Scenario 1, where the curtailment is from Africa, yields the lowest average total revenue across all scenarios. Overall, the difference in average total revenue across regions between Alternative 1 and 2 is not that significant. Even though Alternative 1 yields slightly higher revenue, if we refer to **TABLE 13** on the range of revenue, Alternative 2 slightly generate 0.75% higher maximum range of total revenue compared to Alternative 1. It can be concluded that based on the analysis, prioritizing the empty containers to deficit regions will not significantly affect the overall revenue generated within the company.

7. Conclusion, Recommendations and Limitations

7.1 Conclusion

This study explores comparative revenue analysis with two distinct strategies for container management in European exports: the company's current focus on maximizing laden container shipments and the alternative approach of prioritizing empty container relocation to deficit regions. The findings, structured around key sub-questions, provide insight into the operational, financial, and strategic implications of each approach. Through a detailed analysis, this discussion aims to synthesize these insights, evaluating how each strategy affects revenue, operational efficiency, and risk management in the context of the shipping industry's unique challenges.

The model developed successfully provided shipping companies with data-driven insights into container allocation alternatives, identifying which strategy is more profitable in terms of revenue generation for supporting export operations within Europe.

The following will discuss sub-questions and their answers as presented:

SQ1. What is container repositioning and key factors influencing it in the decision-making process in different regions?

Container relocation, also referred to as empty container repositioning, involves moving empty containers from surplus regions to deficit regions to balance supply and demand, as described in Braekers et al. (2011). Decision-making in empty container repositioning is influenced by several factors, including dynamics behavior of supply and demand, uncertainties in demand, handling, and transportation, variations in container types, gaps in the transport chain, and the strategic and operational choices of carriers. Considering these factors, certain parameters are crucial for revenue analysis across different alternatives, such as freight rates, utilization rates, demand in areas with container deficits, opportunity costs, and transit times.

SQ2. What revenue analysis model can be constructed to evaluate the different container allocation alternatives amid trade imbalances?

A Monte Carlo simulation-based revenue analysis model evaluates various container allocation strategies amid trade imbalances by incorporating key variables like freight rates, utilization rates, transit times, and opportunity costs. This model simulates different scenarios to capture the variability of outcomes, assess the correlation of each parameter and parameter distribution, and make informed decisions on container allocation. By defining parameters and relationships among these factors, this model facilitates a robust analysis of revenue implications under varying market conditions. The stochastic nature of Monte Carlo simulations allows the model to reflect real-world uncertainties, aiding in comprehensive decision-making for container allocation across surplus and deficit regions.

SQ3. How can this model be applied in real-world scenarios to enhance decision-making processes for container allocation in deficit regions?

The revenue model can be applied to real-world data, such as current freight rates, regional demands, and transit times, to simulate and evaluate container allocation strategies. For instance, in a case study with Maersk, real-time data inputs enable the Monte Carlo model to assess revenue implications across different container allocation alternatives. This application provides actionable insights, showing how prioritizing empty containers for deficit regions might affect revenue compared to maintaining regular export routes. The model's flexibility in handling diverse scenarios, such as fluctuating demand or changing economic conditions, allows companies to make informed, data-driven decisions in managing trade imbalances effectively.

SQ4. What are the revenue implications of prioritizing empty container allocation to deficit regions compared to the company's current approach?

Overall total revenue when prioritizing empty container allocation to deficit regions compared to maintaining the export level alternative shows minimal effect due to the slight differences in both total revenues. In terms of total revenues, maintaining export level alternative's (Alternative 1) yield slightly higher total revenues. However, if we look at the range of total revenues generated in Far East after curtailment, prioritizing empty containers to deficit regions depicted (Alternative 2) slightly higher range compared to Alternative 1 with the increase on total revenue's range about 0.75%. However, this increase is not significant compared to the annual growth of revenue in the shipping industry which accounts for 2.7% per year (Cargo Shipping Market Revenue, 2024). In addition to the small increase in total revenue range in Alternative 2, the variation of total revenue in each region also increases. In the context of seasonality, the data distribution in Africa and Latin Africa shows no significant difference when performing Alternative 2. Far East and North America are affected by the seasonality due to their higher volume of trade. Amid these notable differences, seasonality does not affect the range of revenue in each region, but it makes the revenue more stable due to the nature of high contractual customer percentage in Maersk. This nature makes the demand more predictable.

Hence, it can be concluded that the main research question of "**How does the company's current approach to managing European exports compare in terms of revenue to prioritizing empty containers for relocation to areas with deficits**" can be concluded as below:

"*Prioritizing the relocation of empty containers to deficit regions has only a marginal impact on total profitability when compared to maintaining export volumes. While relocating empty containers addresses trade imbalances and reduces container deficits, the additional revenue generated from this strategy remains minimal relative to full export shipments. The primary reason for this is the lower profitability associated with moving empty containers compared to fully laden ones, particularly on routes like Far East–Europe, which show the greatest variability in potential profit*."

7.2 Recommendation

Building on these key findings, there are some recommendations from the analysis. Since there will be time where prioritizing the empty containers allocation to deficit regions is inevitable, there are several approaches that can be executed:

3. Maintain 100% outbound utilization on European-to-Far East journeys as a pre-requisite to achieve higher potential total revenue in Alternative 2, as seen in the analysis. Due to their perfect correlation, an increase in outbound utilization should also result in an increase in return utilization.

4. If the minimal gaps of revenue matters, perform curtailing of outbound trade from Latin America, where curtailing has a minimal financial impact and generating higher revenue compared to curtailment from two other regions. Avoid aggressive curtailing in regions like Africa and where revenue is driven by high utilization and outbound trade volumes.

In the context of maintaining export level, several aspects need to be considered to maintain higher revenue implication as below:

5. Maintain optimum return freight rates and transit time return since both aspects influence total revenue and total revenue per day
6. Carefully determine the freight rate return and outbound of Africa, especially the outbound rates since it has a higher degree of influence on revenue outcomes.
7. Maintain optimum outbound and return freight rates in Latin America since both parameters affected the total revenue and total revenue per day.
8. Maintaining high outbound rates and low transit days (outbound and return) can improve revenue outcomes.

7.3 Limitations and Further Research

While this study has contributed insights into the strategic planning area in the shipping industry, it is essential to acknowledge certain limitations that may have influenced the findings.

1. This thesis does not explore the environmental impacts of the various operational scenarios considered. As such, any environmental consequences associated with the chosen scenarios must be examined, which may limit the comprehensive understanding of sustainable shipping.
2. While this thesis analyzes revenue at a regional level, future research could undertake a more granular assessment by evaluating revenue per individual port call. This approach would provide deeper insights into specific port performance and allow a more nuanced understanding of revenue variations across different locations.
3. Regarding freight rate analysis, this study only considers ocean freight rates and spot market rates. Future research could expand the freight rate analysis to include these additional charges, yielding a more comprehensive financial assessment of shipping costs, empty repositioning cost, and freight rate with contractual customers.
4. The current study does not analyze the cost structure of the transactions, leaving out other associated fees, such as repositioning costs, customs charges, loading and unloading costs, and contractual rates. In addition, the current study focuses exclusively on vessels operated by Maersk (owned and chartered vessels), omitting an analysis of ships from alliances. This focus will also impact the cost structure and the profit margin generated from operating owned and chartered vessels. Hence, for further detailed analysis, it would be nice to associate the cost structure in the analysis for deeper study, not only considering the freight rate.
5. For transit time considerations, this thesis only accounts for time spent on transit on the water. A more detailed analysis could include port-related times, such as gate-in processing, unloading, loading, and gate-out processing. By incorporating these stages, future research would provide a more accurate depiction of total transit time, highlighting areas that impact overall efficiency and profitability.

6. The formula for each parameter should be developed uniquely for each case study or company. This allows different companies to adjust the formulas to align with their specific operational frameworks. These can also be incorporated if additional relevant parameters that align closely with their business model are identified. However, such extensions would be recommended for further research.
7. Finally, this study does not account for additional costs from increased transit times due to port congestion. By integrating costs associated with delays from congestion into future analyses, the revenue calculations would more accurately reflect real-world conditions, offering a more realistic perspective on operational challenges and financial outcomes.

7.4 Reflections

Engaging in this thesis project has been a profoundly enriching experience, allowing me to delve deeply into the complexities of the shipping industry and its multifaceted systems. Through this journey, I deepened my understanding of how revenue in this sector is influenced by various factors, including supply and demand dynamics. Moreover, external variables such as trade imbalances significantly impact on the trade balance within the shipping market, going beyond the general trends of the global economy. Trade imbalances are an ongoing reality, making solutions like empty repositioning crucial. Although repositioning does not directly generate revenue and carries costs, it remains an unavoidable strategy to meet market demands and mitigate equipment imbalances between markets.

My initial interest in exploring the shipping industry was sparked during the Integration Moment (MOT 1003) course. This course provided me with the opportunity to assist a shipping consultancy firm in addressing specific challenges they faced. This experience was pivotal in igniting my curiosity and setting the foundation for the focus of my thesis project.

During this research, the MOT 1531 Digital Business Process Management course proved invaluable. While creating a business process flowchart was not a direct outcome of my thesis, the knowledge gained from this course helped me visualize the framework of my thesis project. It also facilitated my understanding of the business processes executed by the Equipment Flow team, particularly during the validation phase for problem-solving and analysis development.

Additionally, the MOT141A Research Method and MOT111A Financial Management courses significantly contributed to my research capabilities. These courses provided me with a general understanding of how to define and formulate my research while interpreting models using correlation analysis. Moreover, they offered insights into financial aspects critical to my analysis, enabling me to approach my research with a well-rounded perspective.

In conclusion, this research journey has broadened my comprehension of the intricate dynamics of the shipping industry and reinforced my appreciation for interdisciplinary approaches. It has also highlighted the importance of leveraging academic knowledge to address real-world challenges effectively.

Reference

AE7 Eastbound. (2024). https://www.maersk.com/local-information/shipping-from-europe-to-asia-pacific/ae7-eastbound

AE7 Westbound. (2024). https://www.maersk.com/local-information/shipping-from-asia-pacific-to-europe/ae7-westbound

Berk, J., & DeMarzo, P. (2017). Corporate finance: The core (4th Global Edition). Pearson Education Limited.

Boile, M., Theofanis, S., Baveja, A., & Mittal, N. (2008). Regional repositioning of empty containers. Transportation Research Record Journal of the Transportation Research Board, 2066(1), 31–40. https://doi.org/10.3141/2066-04

Braekers, K., Janssens, G. K., & Caris, A. (2011). Challenges in managing empty container movements at multiple planning levels. Transport Reviews, 31(6), 681–708. https://doi.org/10.1080/01441647.2011.584979

Cargo shipping market revenue. (2024, May). https://www.fortunebusinessinsights.com/amp/cargo-shipping-market-102045

Castrellon, J. P., Sanchez-Diaz, I., Roso, V., Altuntas-Vural, C., Rogerson, S., Santén, V., & Kalahasthi, L. K. (2023). Assessing the eco-efficiency benefits of empty container repositioning strategies via dry ports. Transportation Research Part D Transport and Environment, 120, 103778. https://doi.org/10.1016/j.trd.2023.103778

Countries in Latin America & Caribbean. (2024). https://wits.worldbank.org/chatbot/SearchItem.aspx?RegionId=LCN

Countries in Middle East & North Africa. (2024). https://wits.worldbank.org/chatbot/SearchItem.aspx?RegionId=MEA

Countries in North America. (2024). https://wits.worldbank.org/chatbot/SearchItem.aspx?RegionId=NAC

Crainic, T. G., & Laporte, G. (1997). Planning models for freight transportation. European Journal of Operational Research, 97(3), 409–438. https://doi.org/10.1016/s0377-2217(96)00298-6

Crainic, T. G., Gendreau, M., & Dejax, P. (1993). Dynamic and stochastic models for the allocation of empty containers. Operations Research, 41(1), 102–126. https://www.jstor.org/stable/171947

Dejax, P. J., & Crainic, T. G. (1987). SurVey PAPER—A review of empty flows and fleet Management Models in Freight Transportation. Transportation Science, 21(4), 227–248. https://doi.org/10.1287/trsc.21.4.227

Dyna Liners Trades Review. (2006). Annual report PU#0169. Dynamar B.V., Alkmaar, Netherlands.

EPA - Central Africa | Access2Markets. (2024). https://trade.ec.europa.eu/access-to-markets/en/content/epa-central-africa

EPA - Eastern and Southern Africa | Access2Markets. (2024). https://trade.ec.europa.eu/access-to-markets/en/content/epa-eastern-and-southern-africa

EPA SADC - Southern African Development Community | Access2Markets. (2024). https://trade.ec.europa.eu/access-to-markets/en/content/epa-sadc-southern-african-development-community

Fabianová, J., Janeková, J., Fedorko, G., & Molnár, V. (2023). A Comprehensive Methodology for Investment project assessment based on Monte Carlo simulation. Applied Sciences, 13(10), 6103. https://doi.org/10.3390/app13106103

Feltrin, L., & Bertelli, M. (2019). Using clustered heat maps in mineral exploration to visualize Volcanic-Hosted massive sulfide alteration and mineralization. Natural Resources Research, 29(1), 311–344. https://doi.org/10.1007/s11053-019-09586-2

Financial Reports | A.P. Møller - Mærsk A/S. (2023). A.P. Møller - Mærsk a/S. https://investor.maersk.com/financials/financial-reports

Fonseca, M. (2024, September 9). Understanding Correlation Coefficients: A Comprehensive guide for researchers. Editage Insights. https://www.editage.com/insights/understanding-correlation-coefficients-a-comprehensive-guide-for-researchers

Freightos. (2024, July 24). Ocean Freight: Ocean & Sea freight shipping 2024 | FreightOS. https://www.freightos.com/freight-resources/ocean-freight-explained/#-ocean/sea-freight-shipping-ra

GeeksforGeeks. (2020, November 12). Seaborn Heatmap A comprehensive guide. GeeksforGeeks. https://www.geeksforgeeks.org/seaborn-heatmap-a-comprehensive-guide/

GeeksforGeeks. (2024, August 6). Histogram Definition, Types, graph, and examples. GeeksforGeeks. https://www.geeksforgeeks.org/histogram/

GoComet. (2024). Freight Rate Calculator | 20 / 40 ft sea container shipping cost. Container Tracking - GoComet. https://www.gocomet.com/freight-shipping-rates-index-calculator

Guest. (2024, March 13). Shipping companies seeking alternative routes due to Red Sea crisis: How will it impact individual pocket and overall economy. Financial Express. https://www.financialexpress.com/policy/economy-shipping-companies-seeking-alternative-routes-due-to-red-sea-crisis-how-will-it-impact-individual-pocket-and-overall-economy-3423563/

Guo, Z., Wang, W., Tang, G., & Huang, J. (2011). A recursive model for static empty container allocation. Frontiers of Computer Science in China, 5(4), 486–495. https://doi.org/10.1007/s11704-011-1013-y

Gusah, L., Cameron-Rogers, R., & Thompson, R. G. (2019). A systems analysis of empty container logistics – a case study of Melbourne, Australia. Transportation Research Procedia, 39, 92–103. https://doi.org/10.1016/j.trpro.2019.06.011

International Monetary Fund. Research Dept. (2022). How does trade adjust to global disruptions? The role of supply chain habits. IMF eLibrary. https://doi.org/10.5089/9798400200649.053.A005

Janić, M. (2018). Multidimensional examination of the performances of a liner shipping network: trunk line/route operated by conventional (panamax max) and mega (ulc - ultra large container) ships. Journal of Shipping and Trade, 3(1). https://doi.org/10.1186/s41072-018-0039-9

Kose, M. A., Sugawara, N., Terrones, M. E., Prospects Group, & Research Support Team. (2020). Global recessions. In Policy Research Working Paper. https://documents1.worldbank.org/curated/en/185391583249079464/pdf/Global-Recessions.pdf

Leland Wilkinson & Michael Friendly (2009) The History of the Cluster Heat Map, The American Statistician, 63:2, 179-184, DOI: 10.1198/tas.2009.0033

Ligteringen, H. (2021). Ports and terminals. In TU Delft Open eBooks. https://doi.org/10.5074/t.2021.005

Liu, M., Liu, Z., Liu, R., & Sun, L. (2022). Distribution-free approaches for an integrated cargo routing and empty container repositioning problem with repacking operations in liner shipping networks. Sustainability, 14(22), 14773. https://doi.org/10.3390/su142214773

Madsen, N. H. (2024, February 29). Sea-Intelligence - Empty container moves up 20%. https://www.sea-intelligence.com/press-room/253-empty-container-moves-up-20

Nofri, B., Susilawati, A., & Romy, R. (2020). Optimization of gas turbine maintenance scheduling in pln tanjung datuk pekanbaru. Journal of Ocean Mechanical and Aerospace -Science and Engineering- (Jomase), 64(3), 88-93. https://doi.org/10.36842/jomase.v64i3.217

One hundred container ports 2024. (2024). Lloyd's List. https://www.lloydslist.com/one-hundred-container-ports-2024

Prozzi, J., Spurgeon, K., & Harrison, R. (2003). Secret lives of containers: Evidence from Texas. Transportation Research Record: Journal of the Transportation Research Board, 1833, 3–10. Washington, D.C.: Transportation Research Board of the National Academies.

Rook, L. (2024). Research methods: Correlation. Lecture conducted at Delft University of Technology.

Saghari, P. (2023, August 19). Main Container Shipping Routes Busiest Map – nirvana phoenix pars shipping co. https://npp-co.com/learning/main-container-shipping-routes-busiest-map-2/

Sarmadi, K., Amiri-Aref, M., Dong, J., & Hicks, C. (2020). Integrated strategic and operational planning of dry port container networks in a stochastic environment. Transportation Research Part B Methodological, 139, 132–164. https://doi.org/10.1016/j.trb.2020.06.002

SeaRates. (2024). Quote ID: 2136140 / From: Antwerpen / to: Cape Town / USD 504 | SeaRates. SeaRates. https://www.searates.com/logistics-explorer/?id=2136140

Shipadmin. (2024, March 7). Top 5 busiest global shipping routes. Ship4wd. https://ship4wd.com/logistics-shipping/busiest-global-shipping-routes/

Song, D., & Carter, J. (2009). Empty container repositioning in liner shipping1. Maritime Policy and Management/Maritime Policy & Management, 36(4), 291–307. https://doi.org/10.1080/03088830903056934

Song, D., & Dong, J. (2012). Cargo routing and empty container repositioning in multiple shipping service routes. Transportation Research. Part B: Methodological/Transportation Research. Part B, Methodological, 46(10), 1556–1575. https://doi.org/10.1016/j.trb.2012.08.003

Song, D.-P., & Dong, J.-X. (2015). Empty container repositioning. In C.-Y. Lee & Q. Meng (Eds.), Handbook of Ocean Container Transport Logistics [Book-chapter]. https://doi.org/10.1007/978-3-319-11891-8_6

Statista. (2023, October 24). Global container trade by trade lane 2022. https://www.statista.com/statistics/1130550/global-container-trade-by-trade-lane/

Statista. (2024, April 16). Containerized cargo flows 2022, by trade route. https://www.statista.com/statistics/253988/estimated-containerized-cargo-flows-on-major-container-trade-routes/

Statista. (2024a). Extra-EU International Trade | Statista. https://www.statista.com/study/132595/international-trade-of-the-european-union/

Statistics explained. (August, 2024b). https://ec.europa.eu/eurostat/statistics-explained/index.php?title=International_trade_in_goods

Statistics explained. (February, 2024a). https://ec.europa.eu/eurostat/statistics-explained/index.php?title=China-EU_-_international_trade_in_goods_statistics#EU_and_China_in_world_trade_in_goods

Stopford, M. (2009). *Maritime economics* (3rd ed.). Routledge.

Takano, K. and Arai, M. (2011). Study on a liner shipping network design considering empty container reposition. Journal of the Japan Society of Naval Architects and Ocean Engineers, 13, 175-182. https://doi.org/10.2534/jjasnaoe.13.175

Terán, M. A. (2023, September 1). Understanding trucking terms: Headhaul, Deadhead and Backhaul – in North America. Mexicom Logistics. https://mexicomlogistics.com/understanding-trucking-terms-headhaul-deadhead-and-backhaul-in-north-america/

Theofanis, S., & Boilé, M. (2008). Empty marine container logistics: facts, issues and management strategies. GeoJournal, 74(1), 51–65. https://doi.org/10.1007/s10708-008-9214-0

United Nations Conference on Trade and Development. (2022). Review of maritime transport 2022. UNCTAD. https://unctad.org/system/files/official-document/rmt2022_en.pdf

United Nations Conference on Trade and Development. (2023). Review of maritime transport 2023. UNCTAD. https://unctad.org/system/files/official-document/rmt2023_en.pdf

Van Veenstra, A. F. (2005). Empty container reposition: the port of Rotterdam case. In Springer eBooks (pp. 65–76). https://doi.org/10.1007/3-540-27251-8_6

Wang, Q., Wang, Z., & Zheng, J. (2023). Joint optimization of inventory and repositioning for sea empty container based on queuing theory. Journal of Marine Science and Engineering, 11(6), 1097. https://doi.org/10.3390/jmse11061097

Wang, Y., & Meng, Q. (2021). Optimizing freight rate of spot market containers with uncertainties in shipping demand and available ship capacity. Transportation Research Part B Methodological, 146, 314–332. https://doi.org/10.1016/j.trb.2021.02.008

West African Economic and Monetary Union (WAEMU) documents. (2019, April 17). IMF. https://www.imf.org/en/Publications/SPROLLs/WAEMU-362#sort=%40imfdate%20descending

WTO. (April 11, 2024). Leading export countries worldwide in 2023 (in billion U.S. dollars) [Graph]. In Statista. Retrieved September 23, 2024, from https://www.statista.com/statistics/264623/leading-export-countries-worldwide/

Wu, T., Blažek, V., & Schmitt, H. J. (2000). <title>modeling and visualization of photon migration in tissue by monte carlo simulation</title>. SPIE Proceedings. https://doi.org/10.1117/12.407619

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Appendix

Appendix A

1. North America Countries*:

1) Bermuda
2) Canada
3) United States

*Countries in North America, 2024.

2. **Middle East & North Africa Countries*:**

1) United Arab Emirates
2) Bahrain
3) Djibouti
4) Algeria
5) Egypt, Arab Rep.
6) Iran, Islamic Rep.
7) Iraq
8) Israel
9) Jordan
10) Kuwait
11) Lebanon
12) Libya
13) Morocco
14) Oman
15) Qatar
16) Saudi Arabia
17) Syrian Arab Republic
18) Tunisia
19) Yemen

*Countries in Middle East & North Africa, 2024.

1. **Latin America & the Caribbean Countries***:

1) Aruba
2) Argentina
3) Antigua and Barbuda
4) Bahamas
5) Belize
6) Bolivia
7) Brazil
8) Barbados

9) Chile
10) Colombia
11) Costa Rica
12) Cuba
13) Cayman Islands
14) Dominica
15) Dominican Republic
16) Ecuador
17) Grenada
18) Guatemala
19) Guyana
20) Honduras
21) Haiti
22) Jamaica
23) St. Kitts and Nevis
24) St. Lucia
25) Mexico
26) Nicaragua
27) Panama
28) Peru
29) Puerto Rico
30) Paraguay
31) El Salvador
32) Suriname
33) Saint Maarten (Dutch part)
34) Turks and Caicos Islands
35) Trinidad and Tobago
36) Uruguay
37) St. Vincent and the Grenadines
38) Venezuela
39) Virgin Islands (U.S.)

*Countries in Latin America & Caribbean, 2024.)

2. **West Africa Countries***:
   1) Benin
   2) Burkina Faso
   3) Côte D'Ivoire
   4) Guinea-Bissau
   5) Mali
   6) Niger
   7) Senegal

8) Togo

*West African Economic and Monetary Union (WAEMU) Documents, 2019

3. **Central Africa Countries***:
    1) Cameroon

*EPA - Central Africa | Access2Markets, 2024.

4. **Eastern and Southern Africa Countries***:
    1) Comoros
    2) Madagascar
    3) Mauritius
    4) Seychelles
    5) Zimbabwe

*EPA - Eastern and Southern Africa | Access2Markets, 2024.

5. **Southern Africa Countries***:
    1) Botswana
    2) Lesotho
    3) Mozambique
    4) Namibia
    5) South Africa
    6) Eswatini (Swaziland)

*EPA SADC - Southern African Development Community | Access2Markets, 2024.

Appendix B

Monthly data for Seasonality Test in Alternative 2

Month of Departure	Region	Total Full TEU	Total Empty TEU	Freight Rate per TEU	Average Transit Days	Operational Allowance (TEU)
January	EU to Far East	43,891.48	8,211.17	228.00	54.00	57,009.45
January	Far East to EU	176,607.95	1,319.07	2,202.00	48.00	180,689.99
January	EU to Africa	9,101.89	642.52	1,943.00	31.00	11,652.73
January	Africa to EU	9,675.58	662.65	1,109.00	33.00	12,262.48
January	EU to Latin America	9,275.91	155.46	1,034.00	27.00	10,966.62
January	Latin America to EU	18,957.73	972.57	1,318.00	22.00	27,508.01
January	EU to North America	61,838.96	705.02	1,722.00	17.00	69,993.58
January	North America to EU	20,462.42	1,285.68	799.00	16.00	26,567.65
February	EU to Far East	54,676.13	10,228.75	228.00	54.00	65,521.75
February	Far East to EU	126,053.03	1,764.67	2,202.00	48.00	148,502.29

Month of Departure	Region	Total Full TEU	Total Empty TEU	Freight Rate per TEU	Average Transit Days	Operational Allowance (TEU)
February	EU to Africa	7,860.17	672.65	1,943.00	31.00	9,953.84
February	Africa to EU	8,949.61	517.48	1,109.00	33.00	10,156.27
February	EU to Latin America	9,174.72	166.53	1,034.00	27.00	10,686.89
February	Latin America to EU	18,232.92	387.56	1,318.00	22.00	24,687.74
February	EU to North America	43,359.23	650.05	1,722.00	17.00	49,659.88
February	North America to EU	19,055.55	240.83	799.00	16.00	23,096.68
March	EU to Far East	57,249.39	10,710.15	228.00	54.00	82,833.89
March	Far East to EU	175,142.41	289.06	2,202.00	48.00	185,871.76
March	EU to Africa	8,333.33	968.41	1,943.00	31.00	10,817.64
March	Africa to EU	11,516.05	724.28	1,109.00	33.00	14,710.20
March	EU to Latin America	9,427.31	292.13	1,034.00	27.00	10,262.11
March	Latin America to EU	20,959.77	237.52	1,318.00	22.00	27,706.72
March	EU to North America	57,702.86	935.40	1,722.00	17.00	68,164.35
March	North America to EU	22,938.23	331.01	799.00	16.00	23,777.54
April	EU to Far East	67,338.87	12,597.68	228.00	54.00	86,704.75
April	Far East to EU	188,532.83	150.02	2,202.00	48.00	198,751.66
April	EU to Africa	8,195.07	962.76	1,943.00	31.00	10,785.59
April	Africa to EU	8,998.74	700.13	1,109.00	33.00	12,780.94
April	EU to Latin America	8,882.46	340.45	1,034.00	27.00	10,211.69
April	Latin America to EU	22,344.97	352.02	1,318.00	22.00	29,902.38
April	EU to North America	53,185.12	979.03	1,722.00	17.00	68,986.70
April	North America to EU	18,471.32	268.79	799.00	16.00	23,875.37
May	EU to Far East	48,594.97	9,091.09	228.00	54.00	69,797.73
May	Far East to EU	204,847.55	65.40	2,202.00	48.00	221,633.84
May	EU to Africa	8,838.65	1,390.48	1,943.00	31.00	11,853.73
May	Africa to EU	7,539.32	692.93	1,109.00	33.00	12,026.75
May	EU to Latin America	9,389.06	339.29	1,034.00	27.00	11,394.56
May	Latin America to EU	22,639.75	560.96	1,318.00	22.00	29,909.50
May	EU to North America	51,609.69	959.29	1,722.00	17.00	61,385.59
May	North America to EU	19,444.65	430.52	799.00	16.00	27,876.82
June	EU to Far East	51,851.78	9,700.37	228.00	54.00	79,614.63
June	Far East to EU	223,398.31	430.85	2,202.00	48.00	248,400.04

Month of Departure	Region	Total Full TEU	Total Empty TEU	Freight Rate per TEU	Average Transit Days	Operational Allowance (TEU)
June	EU to Africa	8,107.18	918.09	1,943.00	31.00	10,464.93
June	Africa to EU	8,352.01	869.15	1,109.00	33.00	13,585.84
June	EU to Latin America	8,058.88	299.57	1,034.00	27.00	10,397.01
June	Latin America to EU	20,537.74	819.49	1,318.00	22.00	27,063.73
June	EU to North America	46,013.95	764.94	1,722.00	17.00	58,352.74
June	North America to EU	19,615.64	423.95	799.00	16.00	26,983.63
July	EU to Far East	52,597.23	9,839.83	228.00	54.00	68,912.88
July	Far East to EU	178,869.44	1,857.52	2,202.00	48.00	193,001.36
July	EU to Africa	8,107.18	918.09	1,943.00	31.00	10,464.93
July	Africa to EU	10,815.33	946.43	1,109.00	33.00	16,149.64
July	EU to Latin America	126,459.87	3,563.88	1,034.00	27.00	145,766.92
July	Latin America to EU	23,390.45	1,113.54	1,318.00	22.00	31,016.52
July	EU to North America	63,967.26	790.96	1,722.00	17.00	69,342.26
July	North America to EU	15,479.16	1,492.50	799.00	16.00	25,527.70
August	EU to Far East	64,221.48	12,014.48	228.00	54.00	76,963.39
August	Far East to EU	205,892.00	1,210.22	2,202.00	48.00	199,948.67
August	EU to Africa	9,792.89	906.19	1,943.00	31.00	12,342.97
August	Africa to EU	6,973.82	947.23	1,109.00	33.00	12,916.17
August	EU to Latin America	13,880.03	864.02	1,034.00	27.00	22,230.13
August	Latin America to EU	19,968.52	717.46	1,318.00	22.00	24,803.52
August	EU to North America	64,653.14	1,006.06	1,722.00	17.00	68,954.55
August	North America to EU	18,305.80	2,033.54	799.00	16.00	23,931.17
September	EU to Far East	62,688.10	11,727.62	228.00	54.00	72,812.07
September	Far East to EU	221,396.98	2,205.47	2,202.00	48.00	246,045.15
September	EU to Africa	8,915.76	235.26	1,943.00	31.00	11,008.36
September	Africa to EU	8,937.44	914.90	1,109.00	33.00	15,240.15
September	EU to Latin America	15,060.51	790.47	1,034.00	27.00	23,597.85
September	Latin America to EU	20,428.24	870.06	1,318.00	22.00	26,333.45
September	EU to North America	57,446.08	1,027.41	1,722.00	17.00	62,311.46
September	North America to EU	20,795.12	1,217.31	799.00	16.00	25,276.95
October	EU to Far East	67,594.47	12,645.50	228.00	54.00	73,282.82
October	Far East to EU	163,912.13	285.17	2,202.00	48.00	171,506.82

Month of Departure	Region	Total Full TEU	Total Empty TEU	Freight Rate per TEU	Average Transit Days	Operational Allowance (TEU)
October	EU to Africa	9,632.50	567.56	1,943.00	31.00	11,856.67
October	Africa to EU	6,637.83	936.44	1,109.00	33.00	13,716.45
October	EU to Latin America	13,937.29	796.77	1,034.00	27.00	22,453.61
October	Latin America to EU	21,416.19	1,409.65	1,318.00	22.00	28,894.14
October	EU to North America	62,805.89	736.80	1,722.00	17.00	63,746.55
October	North America to EU	16,727.63	1,136.38	799.00	16.00	20,979.09
November	EU to Far East	63,746.02	11,925.53	228.00	54.00	68,802.39
November	Far East to EU	184,797.54	119.38	2,202.00	48.00	187,499.12
November	EU to Africa	8,369.28	1,034.13	1,943.00	31.00	10,250.79
November	Africa to EU	6,674.07	968.57	1,109.00	33.00	12,425.04
November	EU to Latin America	13,023.42	700.48	1,034.00	27.00	20,918.66
November	Latin America to EU	18,740.51	700.80	1,318.00	22.00	24,860.03
November	EU to North America	57,296.40	788.78	1,722.00	17.00	60,658.40
November	North America to EU	19,223.75	597.17	799.00	16.00	19,875.01
December	EU to Far East	75,550.08	14,133.82	228.00	54.00	80,469.26
December	Far East to EU	210,549.83	304.16	2,202.00	48.00	215,194.30
December	EU to Africa	8,902.94	858.52	1,943.00	31.00	10,601.15
December	Africa to EU	6,930.19	1,002.80	1,109.00	33.00	14,137.06
December	EU to Latin America	13,430.54	806.95	1,034.00	27.00	23,156.96
December	Latin America to EU	22,383.20	964.36	1,318.00	22.00	28,864.27
December	EU to North America	50,121.42	683.26	1,722.00	17.00	55,796.96
December	North America to EU	19,480.74	628.31	799.00	16.00	24,379.40

Appendix C

Variability of Freight Rate for Seasonality Testing in Alternative 2

Month of Departure	Region	Var Max_Freight Rate per TEU	Var Min_Freight Rate per TEU
January	Far East to EU	0.25	(0.05)
February	Far East to EU	0.04	(0.12)
March	Far East to EU	0.16	(0.20)
April	Far East to EU	0.24	(0.16)
May	Far East to EU	0.24	(0.01)
June	Far East to EU	0.27	(0.12)
July	Far East to EU	0.26	(0.19)
August	Far East to EU	0.23	0.04
September	Far East to EU	0.25	0.07
October	Far East to EU	0.21	(0.14)
November	Far East to EU	0.19	(0.01)
December	Far East to EU	0.30	(0.15)
January	EU to Far East	0.08	(0.09)
February	EU to Far East	0.23	(0.01)
March	EU to Far East	0.10	(0.15)
April	EU to Far East	0.22	(0.09)
May	EU to Far East	0.14	(0.07)
June	EU to Far East	0.13	(0.06)
July	EU to Far East	0.20	(0.20)
August	EU to Far East	0.13	(0.06)
September	EU to Far East	0.15	(0.14)
October	EU to Far East	0.13	(0.08)
November	EU to Far East	0.15	(0.14)
December	EU to Far East	0.30	0.01
January	EU to Africa	0.25	(0.01)
February	EU to Africa	0.25	(0.07)
March	EU to Africa	0.21	(0.07)
April	EU to Africa	0.22	(0.20)
May	EU to Africa	0.24	(0.02)
June	EU to Africa	0.18	(0.09)
July	EU to Africa	0.27	(0.15)
August	EU to Africa	0.26	0.07
September	EU to Africa	0.24	0.20
October	EU to Africa	0.29	0.07
November	EU to Africa	0.29	(0.15)
December	EU to Africa	0.30	(0.12)

Month of Departure	Region	Var Max_Freight Rate per TEU	Var Min_Freight Rate per TEU
January	Africa to EU	0.15	0.05
February	Africa to EU	0.29	(0.15)
March	Africa to EU	0.25	(0.01)
April	Africa to EU	0.16	(0.17)
May	Africa to EU	0.10	(0.11)
June	Africa to EU	0.23	(0.13)
July	Africa to EU	0.30	(0.13)
August	Africa to EU	0.07	(0.10)
September	Africa to EU	0.11	(0.08)
October	Africa to EU	0.19	(0.14)
November	Africa to EU	0.10	(0.19)
December	Africa to EU	0.06	(0.20)
January	EU to Latin America	(0.19)	(0.20)
February	EU to Latin America	(0.19)	(0.20)
March	EU to Latin America	(0.19)	(0.20)
April	EU to Latin America	(0.19)	(0.20)
May	EU to Latin America	(0.19)	(0.20)
June	EU to Latin America	(0.19)	(0.20)
July	EU to Latin America	0.30	(0.20)
August	EU to Latin America	(0.18)	(0.20)
September	EU to Latin America	(0.18)	(0.19)
October	EU to Latin America	(0.18)	(0.19)
November	EU to Latin America	(0.19)	(0.20)
December	EU to Latin America	(0.19)	(0.20)
January	Latin America to EU	0.19	(0.08)
February	Latin America to EU	0.20	(0.06)
March	Latin America to EU	0.23	(0.04)
April	Latin America to EU	0.30	(0.20)
May	Latin America to EU	0.23	0.11
June	Latin America to EU	0.29	(0.10)
July	Latin America to EU	0.23	(0.20)
August	Latin America to EU	0.22	(0.10)
September	Latin America to EU	0.23	(0.13)
October	Latin America to EU	0.23	(0.06)
November	Latin America to EU	0.19	(0.03)
December	Latin America to EU	0.21	(0.13)
January	EU to North America	0.23	(0.03)
February	EU to North America	0.08	(0.10)
March	EU to North America	0.15	(0.01)

Month of Departure	Region	Var Max_Freight Rate per TEU	Var Min_Freight Rate per TEU
April	EU to North America	0.13	(0.14)
May	EU to North America	0.10	(0.01)
June	EU to North America	0.14	(0.15)
July	EU to North America	0.30	(0.20)
August	EU to North America	0.28	0.06
September	EU to North America	0.20	(0.20)
October	EU to North America	0.23	(0.06)
November	EU to North America	0.16	(0.02)
December	EU to North America	0.18	(0.15)
January	North America to EU	0.16	(0.00)
February	North America to EU	0.25	(0.15)
March	North America to EU	0.23	0.00
April	North America to EU	0.30	(0.20)
May	North America to EU	0.17	(0.17)
June	North America to EU	0.27	(0.04)
July	North America to EU	0.10	(0.09)
August	North America to EU	0.14	(0.12)
September	North America to EU	0.29	(0.06)
October	North America to EU	0.20	(0.02)
November	North America to EU	0.15	(0.06)
December	North America to EU	0.14	(0.06)

Appendix D

Variability of Additional Empties for Repositioning for Seasonality Testing in Alternative 2

Month of Departure	Region	Var Max_Additional Empties for repositioning (TEU)	Var Min_Additional Empties for repositioning (TEU)
January	Far East to EU	1,084.17	73.40
February	Far East to EU	1,374.03	465.39
March	Far East to EU	1,718.62	351.65
April	Far East to EU	891.65	363.93
May	Far East to EU	1,461.94	647.73
June	Far East to EU	1,397.86	608.26
July	Far East to EU	1,054.19	145.15
August	Far East to EU	785.78	306.57
September	Far East to EU	752.00	187.48
October	Far East to EU	787.41	329.33
November	Far East to EU	743.56	184.90
December	Far East to EU	1,231.69	320.33

Month of Departure	Region	Var Max_Additional Empties for repositioning (TEU)	Var Min_Additional Empties for repositioning (TEU)
January	EU to Far East	1,084.17	73.40
February	EU to Far East	1,374.03	465.39
March	EU to Far East	1,718.62	351.65
April	EU to Far East	891.65	363.93
May	EU to Far East	1,461.94	647.73
June	EU to Far East	1,397.86	608.26
July	EU to Far East	1,054.19	145.15
August	EU to Far East	785.78	306.57
September	EU to Far East	752.00	187.48
October	EU to Far East	787.41	329.33
November	EU to Far East	743.56	184.90
December	EU to Far East	1,231.69	320.33

Appendix E

Top 100 ports with highest throughput in 2023 (One Hundred Container Ports 2024, 2024.)

No	Port Name	Country	Region
1	Shanghai	China	Asia
2	Singapore	Singapore	Asia
3	Ningbo-Zhoushan	China	Asia
4	Shenzhen	China	Asia
5	Qingdao	China	Asia
6	Guangzhou	China	Asia
7	Busan	South Korea	Asia
8	Tianjin	China	Asia
9	Dubai	United Arab Emirates	MENAT
10	Hong Kong	China	Asia
11	Port Klang	Malaysia	Asia
12	Rotterdam	The Netherlands	EU
13	Xiamen	China	Asia
14	Antwerp-Bruges	Belgium	EU
15	Tanjung Pelepas	Malaysia	Asia
16	Laem Chabang	Thailand	Asia
17	Kaohsiung	Taiwan	Asia
18	Los Angeles	United States	NAM
19	Tanger Med	Morocco	MENAT
20	Taicang	China	Asia
21	Long Beach	United States	NAM
22	New York/New Jersey	United States	NAM
23	Hamburg	Germany	EU

No	Port Name	Country	Region
24	Mundra	India	Asia
25	Ho Chi Minh City	Vietnam	Asia
26	Tanjung Priok	Indonesia	Asia
27	Colombo	Sri Lanka	Asia
28	Jawaharlal Nehru	India	Asia
29	Savannah	United States	NAM
30	Rizhao	China	Asia
31	Hai Phong	Vietnam	Asia
32	Cai Mep	Vietnam	Asia
33	Lianyungang	China	Asia
34	Manila	Philippines	Asia
35	Qinzhou	China	Asia
36	Colón	Panama	LAM
37	Valencia	Spain	EU
38	Piraeus	Greece	EU
39	Yingkou	China	Asia
40	Santos	Brazil	LAM
41	Jeddah	Saudi Arabia	MENAT
42	Algeciras	Spain	Asia
43	Bremen/Bremerhaven	Germany	EU
44	Salalah	Oman	MENAT
45	Dalian	China	Asia
46	Tokyo	Japan	Asia
47	Abu Dhabi	United Arab Emirates	MENAT
48	Port Said	Egypt	MENAT
49	Yantai	China	Asia
50	Houston	United States	NAM
51	Tanjung Perak	Indonesia	Asia
52	Virginia	United States	NAM
53	Vancouver	Canada	NAM
54	Barcelona	Spain	Asia
55	Manzanillo	Mexico	LAM
56	Fuzhou	China	Asia
57	Dongguan	China	Asia
58	Seattle/Tacoma	United States	NAM
59	Gioia Tauro	Italy	Asia
60	Balboa	Panama	LAM
61	Tangshan	China	Asia
62	Melbourne	Australia	Asia
63	Felixstowe	United Kingdom	EU
64	London	United Kingdom	EU
65	Nanjing	China	Asia
66	Incheon	South Korea	Asia
67	Chittagong	Bangladesh	Asia

No	Port Name	Country	Region
68	Cartagena	Colombia	LAM
69	Le Havre	France	EU
70	Yokohama	Japan	Asia
71	King Abdullah	Saudi Arabia	MENAT
72	Kobe	Japan	Asia
73	Marsaxlokk	Malta	MENAT
74	Ambarli	Turkey	MENAT
75	Jiaxing	China	Asia
76	Sydney	Australia	Asia
77	Charleston	United States	NAM
78	Nagoya	Japan	Asia
79	Durban	South Africa	South Africa
80	Genoa	Italy	EU
81	Callao	Peru	LAM
82	Osaka	Japan	Asia
83	Oakland	United States	NAM
84	Nantong	China	Asia
85	Kingston	Jamaica	NAM
86	Haikou	China	Asia
87	Quanzhou	China	Asia
88	Gdansk	Poland	EU
89	Kocaeli	Turkey	MENAT
90	Dammam	Saudi Arabia	MENAT
91	Lázaro Cárdenas	Mexico	LAM
92	Mersin	Turkey	MENAT
93	Guayaquil	Ecuador	LAM
94	Lomé	Togo	West Africa
95	Jinzhou	China	Asia
96	Yeosu Gwangyang	South Korea	Asia
97	Southampton	United Kingdom	EU
98	Taipei	Taiwan	Asia
99	Taichung	Taiwan	Asia
100	Tekirdag	Asyaport & Ceyport Tekirdag (Turkey)	MENAT

Appendix F

1. Far East Freight Rate

a. Return Journey

Port of destination	Country	Region	Port of loading	Country	Region	Freight Rate (USD)	Transit times (days)
Rotterdam	The Netherlands	EU	Shanghai	China	Asia	2,255	36
			Ningbo-Zhoushan	China	Asia	1,925	39
			Tianjin	China	Asia	1,665	47
			Xiamen	China	Asia	-	-
			Qinzhou	China	Asia	-	-
Antwerp-Bruges	Belgium	EU	Shanghai	China	Asia	2,255	48
			Ningbo-Zhoushan	China	Asia	1,930	46
			Tianjin	China	Asia	-	-
			Xiamen	China	Asia	-	-
			Qinzhou	China	Asia	2,239	53
Hamburg	Germany	EU	Shanghai	China	Asia	1,650	43
			Ningbo-Zhoushan	China	Asia	1,925	46
			Tianjin	China	Asia	-	-
			Xiamen	China	Asia	-	-
			Qinzhou	China	Asia	2,239	49
Valencia	Spain	EU	Shanghai	China	Asia	2,202	38
			Ningbo-Zhoushan	China	Asia	2,202	40
			Tianjin	China	Asia	-	-
			Xiamen	China	Asia	-	-
			Qinzhou	China	Asia	2,455	42
Piraeus	Greece	EU	Shanghai	China	Asia	1,914	60
			Ningbo-Zhoushan	China	Asia	2,706	56
			Tianjin	China	Asia	-	-
			Xiamen	China	Asia	2,706	61
			Qinzhou	China	Asia	2,959	58
				Average		**2,202**	**48**
				Freight Rates/day		**46**	

b. Outbound Journey

Port of loading	Country	Region	ort of destination	Country	Region	Freight Rate (USD)	ransit times (days)
Rotterdam	The Netherlands	EU	Shanghai	China	Asia	39	37
			Ningbo-Zhoushan	China	Asia	-	-
			Tianjin	China	Asia	-	-
			Xiamen	China	Asia	-	-
			Qinzhou	China	Asia	-	-
Antwerp-Bruges	Belgium	EU	Shanghai	China	Asia	154	70
			Ningbo-Zhoushan	China	Asia	154	72
			Tianjin	China	Asia	99	49
			Xiamen	China	Asia	732	53
			Qinzhou	China	Asia	-	-
Hamburg	Germany	EU	Shanghai	China	Asia	-	-
			Ningbo-Zhoushan	China	Asia	248	54
			Tianjin	China	Asia	-	-
			Xiamen	China	Asia	-	-
			Qinzhou	China	Asia	-	-
Valencia	Spain	EU	Shanghai	China	Asia	-	-
			Ningbo-Zhoushan	China	Asia	-	-
			Tianjin	China	Asia	-	-
			Xiamen	China	Asia	-	-
			Qinzhou	China	Asia	-	-
Piraeus	Greece	EU	Shanghai	China	Asia	-	-
			Ningbo-Zhoushan	China	Asia	346	52
			Tianjin	China	Asia	-	-
			Xiamen	China	Asia	55	45
			Qinzhou	China	Asia	-	-
				Average		**228**	**54**
				Freight Rates/day		**4**	

2. Latin America Freight Rate

a. Return Journey

ort of destination	Country	Region	Port of loading	Country	Region	reight Rate (USD)	Transit times (days)
Rotterdam	The Netherlands	EU	Colón	Panama	LAM	-	-
			Santos	Brazil	LAM	1,290	17
			Manzanillo	Mexico	LAM	1,448	38
			Balboa	Panama	LAM	591	16
			Cartagena	Colombia	LAM	-	-
Antwerp-Bruges	Belgium	EU	Colón	Panama	LAM	-	-
			Santos	Brazil	LAM	1,303	25
			Manzanillo	Mexico	LAM	1,338	29
			Balboa	Panama	LAM	480	14
			Cartagena	Colombia	LAM	372	20
Hamburg	Germany	EU	Colón	Panama	LAM	-	-
			Santos	Brazil	LAM	1,294	19
			Manzanillo	Mexico	LAM	2,444	21
			Balboa	Panama	LAM	-	-
			Cartagena	Colombia	LAM	658	16
Valencia	Spain	EU	Colón	Panama	LAM	-	-
			Santos	Brazil	LAM	1,364	21
			Manzanillo	Mexico	LAM	-	-
			Balboa	Panama	LAM	-	-
			Cartagena	Colombia	LAM	-	-
Piraeus	Greece	EU	Colón	Panama	LAM	-	-
			Santos	Brazil	LAM	1,558	27
			Manzanillo	Mexico	LAM	3,307	29
			Balboa	Panama	LAM	-	-
			Cartagena	Colombia	LAM	999	21
				Average		**1,318**	**22**
				Freight Rates/day		**59**	

b. Outbound Journey

Port of loading	Country	Region	Port of destination	Country	Region	Freight Rate (USD)	Transit times (days)
Rotterdam	The Netherlands	EU	Colón	Panama	LAM	-	-
			Santos	Brazil	LAM	71	26
			Manzanillo	Mexico	LAM	1,000	33
			Balboa	Panama	LAM	1,347	19
			Cartagena	Colombia	LAM	-	-
Antwerp-Bruges	Belgium	EU	Colón	Panama	LAM	-	-
			Santos	Brazil	LAM	71	19
			Manzanillo	Mexico	LAM	-	-
			Balboa	Panama	LAM	-	-
			Cartagena	Colombia	LAM	1,094	18
Hamburg	Germany	EU	Colón	Panama	LAM	-	-
			Santos	Brazil	LAM	71	23
			Manzanillo	Mexico	LAM	1,340	30
			Balboa	Panama	LAM	1,616	16
			Cartagena	Colombia	LAM	1,182	13
Valencia	Spain	EU	Colón	Panama	LAM	-	-
			Santos	Brazil	LAM	180	26
			Manzanillo	Mexico	LAM	-	-
			Balboa	Panama	LAM	-	-
			Cartagena	Colombia	LAM	-	-
Piraeus	Greece	EU	Colón	Panama	LAM	-	-
			Santos	Brazil	LAM	284	31
			Manzanillo	Mexico	LAM	2,417	48
			Balboa	Panama	LAM	2,137	35
			Cartagena	Colombia	LAM	1,665	40
				Average		**1,034**	**27**
				Freight Rates/day		**38**	

3. North America Freight Rate

a. Return Journey

Port of destination	Country	Region	Port of loading	Country	Region	Freight Rate (USD)	Transit times (days)
Rotterdam	The Netherlands	EU	Los Angeles	United States	NAM	800	15
			Long Beach	United States	NAM	800	24
			New York/New Jersey	United States	NAM	800	10
			Savannah	United States	NAM	800	12
			Houston	United States	NAM	800	16
Antwerp-Bruges	Belgium	EU	Los Angeles	United States	NAM	500	24
			Long Beach	United States	NAM	500	15
			New York/New Jersey	United States	NAM	500	10
			Savannah	United States	NAM	500	12
			Houston	United States	NAM	500	16
Hamburg	Germany	EU	Los Angeles	United States	NAM	594	15
			Long Beach	United States	NAM	594	25
			New York/New Jersey	United States	NAM	594	11
			Savannah	United States	NAM	594	13
			Houston	United States	NAM	594	16
Valencia	Spain	EU	Los Angeles	United States	NAM	-	-
			Long Beach	United States	NAM	-	-
			New York/New Jersey	United States	NAM	-	-
			Savannah	United States	NAM	-	-
			Houston	United States	NAM	-	-
Piraeus	Greece	EU	Los Angeles	United States	NAM	1,300	18
			Long Beach	United States	NAM	1,300	18
			New York/New Jersey	United States	NAM	1,300	14
			Savannah	United States	NAM	1,300	16
			Houston	United States	NAM	1,300	18
				Average		**799**	**16**
				Freight Rates/day		**50**	

b. Outbound Journey

Port of loading	Country	Region	Port of destination	Country	Region	Freight Rate (USD)	Transit times (days)
Rotterdam	The Netherlands	EU	Los Angeles	United States	NAM	3,693.2	24
			Long Beach	United States	NAM	3,693.2	24
			New York/New Jersey	United States	NAM	3,693.2	10
			Savannah	United States	NAM	3,693.2	12
			Houston	United States	NAM	3,693.2	16
Antwerp-Bruges	Belgium	EU	Los Angeles	United States	NAM	1,814.4	15
			Long Beach	United States	NAM	1,814.4	24
			New York/New Jersey	United States	NAM	1,814.4	10
			Savannah	United States	NAM	1,814.4	12
			Houston	United States	NAM	1,814.4	16
Hamburg	Germany	EU	Los Angeles	United States	NAM	3,015.5	25
			Long Beach	United States	NAM	3,015.5	25
			New York/New Jersey	United States	NAM	3,015.5	11
			Savannah	United States	NAM	3,015.5	13
			Houston	United States	NAM	3,015.5	16
Valencia	Spain	EU	Los Angeles	United States	NAM	43.5	25
			Long Beach	United States	NAM	43.5	24
			New York/New Jersey	United States	NAM	43.5	11
			Savannah	United States	NAM	43.5	13
			Houston	United States	NAM	43.5	14
Piraeus	Greece	EU	Los Angeles	United States	NAM	44	27
			Long Beach	United States	NAM	44	18
			New York/New Jersey	United States	NAM	44	14
			Savannah	United States	NAM	44	16
			Houston	United States	NAM	44	19
				Average		**1,722**	**17**
				Freight Rates/day		**99**	

4. Africa Freight Rate

a. Return Journey

Port of destination	Country	Region	Port of loading	Country	Region	Freight Rate (USD)	Transit times (days)
Rotterdam	The Netherlands	EU	Tanger Med	Morocco	MENAT	-	-
			Port Said	Egypt	MENAT	-	-
k			Durban	South Africa	South Africa	1,705	22
			Lomé	Togo	West Africa	-	-
Antwerp-Bruges	Belgium	EU	Tanger Med	Morocco	MENAT	-	-
			Port Said	Egypt	MENAT	-	-
			Durban	South Africa	South Africa	1,796	33
			Lomé	Togo	West Africa	-	-
Hamburg	Germany	EU	Tanger Med	Morocco	MENAT	-	-
			Port Said	Egypt	MENAT	-	-
			Durban	South Africa	South Africa	1,903	34
			Lomé	Togo	West Africa	-	-
Valencia	Spain	EU	Tanger Med	Morocco	MENAT	-	-
			Port Said	Egypt	MENAT	-	-
			Durban	South Africa	South Africa	-	-
			Lomé	Togo	West Africa	1,866	44
Piraeus	Greece	EU	Tanger Med	Morocco	MENAT	-	-
			Port Said	Egypt	MENAT	-	-
			Durban	South Africa	South Africa	2,444	22
			Lomé	Togo	West Africa	-	-
				Average		**1,943**	**31**
				Freight Rates/day		**63**	

b. Outbound Journey

Port of loading	Country	Region	Port of destination	Country	Region	Freight Rate (USD)	Transit times (days)
Rotterdam	The Netherlands	EU	Tanger Med	Morocco	MENAT	-	-
			Port Said	Egypt	MENAT	-	-
			Durban	South Africa	South Africa	576	31
			Lomé	Togo	West Africa	1,492	31
Antwerp-Bruges	Belgium	EU	Tanger Med	Morocco	MENAT	-	-
			Port Said	Egypt	MENAT	-	-
			Durban	South Africa	South Africa	559	41
			Lomé	Togo	West Africa	-	-
Hamburg	Germany	EU	Tanger Med	Morocco	MENAT	-	-
			Port Said	Egypt	MENAT	-	-
			Durban	South Africa	South Africa	569	43
			Lomé	Togo	West Africa	-	-
Valencia	Spain	EU	Tanger Med	Morocco	MENAT	-	-
			Port Said	Egypt	MENAT	-	-
			Durban	South Africa	South Africa	1,012	31
			Lomé	Togo	West Africa	-	-
Piraeus	Greece	EU	Tanger Med	Morocco	MENAT	-	-
			Port Said	Egypt	MENAT	-	-
			Durban	South Africa	South Africa	2,444	22
			Lomé	Togo	West Africa	-	-

Appendix G

Phyton Script for Alternative 1

```
import numpy as np
import pandas as pd

# Load the CSV file
csv_path = 'C:/Users/tinez/JupyterLab - Document/Base Scenario CSV.csv'  # Replace with the actual path to your CSV file
data = pd.read_csv(csv_path)

# Number of simulations
iterations = 500

# Initialize dictionary to store results for all regions
results = {}

# Helper function to calculate revenue and losses for the region pair
def calculate_revenue_for_region(row_outbound, row_return):
   total_revenue = []
   total_revenue_per_day = []
   utilization_rate_outbound = []
   utilization_rate_return = []

   # Convert the Total Full TEU to numeric
   total_full_teu_outbound = pd.to_numeric(row_outbound['Total Full TEU'], errors='coerce')
   total_full_teu_return = pd.to_numeric(row_return['Total Full TEU'], errors='coerce')

   total_empty_teu_outbound = pd.to_numeric(row_outbound['Total Empty TEU'], errors='coerce')
   total_empty_teu_return = pd.to_numeric(row_return['Total Empty TEU'], errors='coerce')

   current_transit_time_outbound = pd.to_numeric(row_outbound['Average Transit Days'], errors='coerce')
   current_transit_time_return = pd.to_numeric(row_return['Average Transit Days'], errors='coerce')

   operational_allowance_outbound = pd.to_numeric(row_outbound['Operational Allowance (TEU)'], errors='coerce')
   operational_allowance_return = pd.to_numeric(row_return['Operational Allowance (TEU)'], errors='coerce')

   # Extract base freight rate from the CSV
   base_freight_rate_outbound = pd.to_numeric(row_outbound['Freight Rate per TEU'], errors='coerce')
   base_freight_rate_return = pd.to_numeric(row_return['Freight Rate per TEU'], errors='coerce')

   # Check if any values are missing or zero
   if pd.isna(total_full_teu_outbound) or pd.isna(total_full_teu_return) or total_full_teu_outbound == 0 or total_full_teu_return == 0:
      print(f"Skipping iteration due to missing or invalid TEU values: Outbound = {total_full_teu_outbound}, Return = {total_full_teu_return}")
      return pd.DataFrame()  # Return an empty DataFrame to skip this iteration

   if pd.isna(operational_allowance_outbound) or pd.isna(operational_allowance_return) or operational_allowance_outbound == 0 or operational_allowance_return == 0:
      print(f"Skipping iteration due to missing or invalid operational allowance")
      return pd.DataFrame()  # Return an empty DataFrame to skip this iteration

   # Set the bounds for the uniform distribution (20% decrease, 30% increase)
   min_freight_rate_outbound = base_freight_rate_outbound * 0.80  # 20% decrease
   max_freight_rate_outbound = base_freight_rate_outbound * 1.30  # 30% increase
   min_freight_rate_return = base_freight_rate_return * 0.80      # 20% decrease
   max_freight_rate_return = base_freight_rate_return * 1.30      # 30% increase

   # Freight rate distribution (uniform distribution)
   freight_rate_distribution_outbound = np.random.uniform(low=min_freight_rate_outbound, high=max_freight_rate_outbound, size=iterations)
   freight_rate_distribution_return = np.random.uniform(low=min_freight_rate_return, high=max_freight_rate_return, size=iterations)

   # Transit times after random increase (5% to 30%)
   transit_time_increase_distribution_outbound = np.random.uniform(low=0.05, high=0.30, size=iterations)
   transit_time_increase_distribution_return = np.random.uniform(low=0.05, high=0.30, size=iterations)

   # Perform the simulation for each pair of trips (outbound and return)
   for i in range(iterations):
      freight_rate_outbound = freight_rate_distribution_outbound[i]
      freight_rate_return = freight_rate_distribution_return[i]

      # Transit times after random increase (5% to 30%)
      transit_time_increase_outbound = transit_time_increase_distribution_outbound[i]
      transit_time_increase_return = transit_time_increase_distribution_return[i]

      # Calculate new transit days after the increase
      new_transit_days_outbound = current_transit_time_outbound * (1 + transit_time_increase_outbound)
      new_transit_days_return = current_transit_time_return * (1 + transit_time_increase_return)

      # Calculate total revenues for outbound and return
      total_revenue_outbound = total_full_teu_outbound * freight_rate_outbound
      total_revenue_return = total_full_teu_return * freight_rate_return

      # Calculate total revenue per day (outbound and return)
      total_revenue_per_day_outbound = total_revenue_outbound / new_transit_days_outbound
      total_revenue_per_day_return = total_revenue_return / new_transit_days_return
```

```
        # Store the calculated total revenue and per day revenues
        total_revenue.append(total_revenue_outbound + total_revenue_return)
        total_revenue_per_day.append(total_revenue_per_day_outbound + total_revenue_per_day_return)

        # Store utilization rates
        utilization_rate_outbound.append(total_full_teu_outbound + total_empty_teu_outbound / operational_allowance_outbound)
        utilization_rate_return.append(total_full_teu_return + total_empty_teu_return / operational_allowance_return)

    # Return results for this region pair
    return pd.DataFrame({
        'Total Revenue': total_revenue,
        'Total Revenue per Day': total_revenue_per_day,
        'Utilization Rate Outbound': utilization_rate_outbound,
        'Utilization Rate Return': utilization_rate_return,
        'Freight Rate per TEU Outbound': freight_rate_distribution_outbound,
        'Freight Rate per TEU Return': freight_rate_distribution_return,
        'Average Transit Days Outbound': current_transit_time_outbound * (1 + transit_time_increase_distribution_outbound),
        'Average Transit Days Return': current_transit_time_return * (1 + transit_time_increase_distribution_return),
    })

# Define outbound and return trip pairs
region_pairs = {
    'Far East from to EU': ('EU to Far East', 'Far East to EU'),
    'Africa from to EU': ('EU to Africa', 'Africa to EU'),
    'Latin America from to EU': ('EU to Latin America', 'Latin America to EU'),
    'North America from to EU': ('EU to North America', 'North America to EU')
}

# Process each pair of regions
for region_pair, (outbound, return_trip) in region_pairs.items():
    row_outbound = data[data['Region'] == outbound].iloc[0]
    row_return = data[data['Region'] == return_trip].iloc[0]

    # Calculate results for the region pair
    results[region_pair] = calculate_revenue_for_region(row_outbound, row_return)

# Analyze results for each region pair
for region_name, result_df in results.items():
    print(f"Summary for {region_name}")
    print(result_df.describe())
    print("\n")
import seaborn as sns
import matplotlib.pyplot as plt
import pandas as pd  # Ensure pandas is imported for DataFrame handling

# Combine all region results into a single DataFrame
all_results = []

for region_name, result_df in results.items():
    result_df['Region'] = region_name  # Add a column for region name
    all_results.append(result_df)

# Concatenate all results into one DataFrame
combined_results = pd.concat(all_results, ignore_index=True)

# Create a FacetGrid for histograms of Total Revenue
g = sns.FacetGrid(combined_results, col="Region", col_wrap=2, height=4, aspect=1.5)
g.map(sns.histplot, "Total Revenue", kde=False, color='skyblue', edgecolor='black')

# Add global axis labels
g.set_axis_labels("Total Revenue", "Frequency")
g.set_ylabels("Frequency", fontsize=16, color="black")
for ax in g.axes.flat:
    ax.set_xlabel("Total Revenue", fontsize=18, color="black")

# Ensure all x-axis tick labels are shown for each subplot
for ax in g.axes.flat:
    ax.tick_params(axis='x', which='both', labelbottom=True)  # Enable x-axis labels for all subplots

# Customize tick labels and rotation
for ax in g.axes.flat:
    ax.tick_params(axis='x', labelsize=16, labelcolor='black', rotation=45)
    ax.tick_params(axis='y', labelsize=14, labelcolor='black')
    # Set x and y tick labels to bold
    for tick in ax.get_xticklabels():
        tick.set_fontweight("bold")
    for tick in ax.get_yticklabels():
        tick.set_fontweight("bold")


# Set titles manually for each subplot
for ax in g.axes.flat:
    ax.set_title(ax.get_title(), fontsize=16, color="black")  # Adjust font size and color

# Add the overall title
g.fig.suptitle('Distribution of Total Revenue Across Region', y=1.05, fontsize=20, color="black")

# Adjust layout and show the plot
```

```
plt.tight_layout()
plt.show()

import seaborn as sns
import matplotlib.pyplot as plt
import pandas as pd  # Ensure pandas is imported for DataFrame handling

# Combine all region results into a single DataFrame
all_results = []

for region_name, result_df in results.items():
    result_df['Region'] = region_name  # Add a column for region name
    all_results.append(result_df)

# Concatenate all results into one DataFrame
combined_results = pd.concat(all_results, ignore_index=True)

# Create a FacetGrid for histograms of Total Revenue per Day
g = sns.FacetGrid(combined_results, col="Region", col_wrap=2, height=4, aspect=1.5)

# Map the histograms to the grid
g.map(plt.hist, "Total Revenue per Day", bins=30, color='skyblue', edgecolor='black')

# Customize axis labels
g.set_axis_labels("Total Revenue per Day", "Frequency")
g.set_xlabels("Total Revenue per Day", fontsize=16, color="black")
g.set_ylabels("Frequency", fontsize=16, color="black")

# Customize tick labels
for ax in g.axes.flat:
    ax.tick_params(axis='x', labelsize=14, labelcolor='black')  # X-axis ticks
    ax.tick_params(axis='y', labelsize=14, labelcolor='black')  # Y-axis ticks

# Set titles manually for each subplot
for ax in g.axes.flat:
    ax.set_title(ax.get_title(), fontsize=16, color="black")  # Adjust font size and color

# Add the overall title
g.fig.suptitle('Distribution of Total Revenue per Day Across Regions', y=1.05, fontsize=20, color="black")

# Adjust layout and show the plot
plt.tight_layout()
plt.show()

import numpy as np
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt

# Initialize an empty DataFrame to store the combined data from all regions
combined_data = pd.DataFrame()

# Loop through all region pairs to aggregate data
for region in ['Far East from to EU', 'Africa from to EU', 'Latin America from to EU', 'North America from to EU']:
    if region in results:
        region_data = results[region].copy()
        region_data['Region'] = region  # Add region identifier
        combined_data = pd.concat([combined_data, region_data], ignore_index=True)

# Select the relevant columns for correlation analysis
columns_for_corr = ['Freight Rate per TEU Outbound', 'Freight Rate per TEU Return',
                'Average Transit Days Outbound', 'Average Transit Days Return',
                'Total Revenue', 'Total Revenue per Day']

# Filter the combined data for these columns
df_for_correlation = combined_data[columns_for_corr]

# Calculate the correlation matrix
correlation_matrix = df_for_correlation.corr()

# Function to determine font color based on cell value
def get_text_color(value, cmap, vmin, vmax):
    norm = plt.Normalize(vmin, vmax)  # Normalize the data to colormap range
    rgba = cmap(norm(value))  # Get RGBA color for the value
    r, g, b, _ = rgba  # Extract RGB values
    brightness = r * 0.299 + g * 0.587 + b * 0.114  # Calculate perceived brightness
    return "white" if brightness < 0.5 else "black"  # White text for dark background

# Create the heatmap
plt.figure(figsize=(15, 12))
cmap = plt.cm.viridis  # Choose a colormap
sns.heatmap(
    correlation_matrix,
    annot=False,  # Turn off annotations in sns.heatmap
    cmap=cmap,
    linewidths=0.5,
    square=True
)
```

```
# Add custom annotations
vmin, vmax = correlation_matrix.min().min(), correlation_matrix.max().max()
for i in range(correlation_matrix.shape[0]):
    for j in range(correlation_matrix.shape[1]):
        value = correlation_matrix.iloc[i, j]
        text_color = get_text_color(value, cmap, vmin, vmax)  # Determine text color
        plt.text(
            j + 0.5, i + 0.5,  # Adjust position
            f"{value:.2f}",  # Format the text
            ha="center", va="center", color=text_color, fontsize=15, fontweight="bold"
        )

# Customize titles and labels
plt.xticks(fontsize=14, rotation=90, fontweight="bold")
plt.yticks(fontsize=14, rotation=0, fontweight="bold")
plt.title("Correlation Heatmap", fontsize=16, color="black", fontweight="bold")

# Save or show the plot
plt.savefig('heatmap_dynamic_font_colors.png', dpi=800, bbox_inches='tight')
plt.show()

import numpy as np
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt

# Select the relevant columns for correlation analysis
columns_for_corr = ['Freight Rate per TEU Outbound', 'Freight Rate per TEU Return',
                    'Average Transit Days Outbound', 'Average Transit Days Return',
                    'Total Revenue', 'Total Revenue per Day']

# Function to determine font color based on cell value
def get_text_color(value, cmap, vmin, vmax):
    norm = plt.Normalize(vmin, vmax)  # Normalize the data to colormap range
    rgba = cmap(norm(value))  # Get RGBA color for the value
    r, g, b, _ = rgba  # Extract RGB values
    brightness = r * 0.299 + g * 0.587 + b * 0.114  # Calculate perceived brightness
    return "white" if brightness < 0.5 else "black"  # White text for dark background

# Loop through each region and calculate the correlation for that specific region
for region in ['Far East from to EU', 'Africa from to EU', 'Latin America from to EU', 'North America from to EU']:

    # Check if the region has data in the results dictionary
    if region not in results:
        print(f"No data available for region: {region}")
        continue

    # Get the region data
    region_data = results[region]

    # Filter the data for the relevant columns
    df_for_correlation = region_data[columns_for_corr]

    # Calculate the correlation matrix for the region
    correlation_matrix = df_for_correlation.corr()

    # Plot the correlation heatmap for the region with dynamic font colors
    plt.figure(figsize=(15, 12))
    cmap = plt.cm.viridis  # Choose a colormap
    sns.heatmap(
        correlation_matrix,
        annot=False,  # Turn off annotations in sns.heatmap
        cmap=cmap,
        linewidths=0.5,
        square=True
    )

    # Add custom annotations
    vmin, vmax = correlation_matrix.min().min(), correlation_matrix.max().max()
    for i in range(correlation_matrix.shape[0]):
        for j in range(correlation_matrix.shape[1]):
            value = correlation_matrix.iloc[i, j]
            text_color = get_text_color(value, cmap, vmin, vmax)  # Determine text color
            plt.text(
                j + 0.5, i + 0.5,  # Adjust position
                f"{value:.2f}",  # Format the text
                ha="center", va="center", color=text_color, fontsize=15, fontweight="bold"
            )

    # Customize titles and labels
    plt.xticks(fontsize=14, rotation=90, fontweight="bold")
    plt.yticks(fontsize=14, rotation=0, fontweight="bold")
    plt.title(f"Correlation Heatmap for {region}", fontsize=16, color="black", fontweight="bold")

    # Save or show the plot
    plt.savefig(f'heatmap_{region.replace(" ", "_").lower()}.png', dpi=800, bbox_inches='tight')  # Save with high resolution
    plt.show()
```

Appendix H

Phyton Script for Alternative 2 (Without Seasonality)

```
import numpy as np
import pandas as pd

# Setelah di masukin impact Loss ke Far East + uncommand print buat only show statistical summary
# Load the CSV file
csv_path = 'C:\\Users\\tinez\\iCloudDrive\\TUD Msc - Tinezhia N\\Thesis\\3. CSV for phyton (backup)\\Full Year 2023 CSV Model.csv' # Replace with the actual path to your CSV file
data = pd.read_csv(csv_path)

# Number of simulations
iterations = 500

# Regions where "Loss of Revenue due to Repositioning" applies
regions_with_loss_of_revenue = [
    "Far East to EU",
    "EU to Africa",
    "EU to Latin America",
    "EU to North America"
]

# Initialize dictionary to store results for all regions
results = {}

# Helper function to calculate revenue and losses for the region pair
def calculate_revenue_for_region(row_outbound, row_return, additional_empties_outbound, additional_empties_return):
    #print(row_outbound['Region'])
    #print(row_return['Region'])
    total_revenue = []
    total_revenue_per_day = []
    utilization_rate_outbound = []
    utilization_rate_return = []
    loss_of_revenue_per_day = []
    total_loss_of_revenue_due_to_repositioning = []

    # Convert the Total Full TEU to numeric (in case it's stored as a string in the CSV)
    total_full_teu_outbound = pd.to_numeric(row_outbound['Total Full TEU'], errors='coerce')
    total_full_teu_return = pd.to_numeric(row_return['Total Full TEU'], errors='coerce')

    total_empty_teu_outbound = pd.to_numeric(row_outbound['Total Empty TEU'], errors='coerce')
    total_empty_teu_return = pd.to_numeric(row_return['Total Empty TEU'], errors='coerce')

    current_transit_time_outbound = pd.to_numeric(row_outbound['Average Transit Days'], errors='coerce')
    current_transit_time_return = pd.to_numeric(row_return['Average Transit Days'], errors='coerce')

    operational_allowance_outbound = pd.to_numeric(row_outbound['Operational Allowance (TEU)'], errors='coerce')
    operational_allowance_return = pd.to_numeric(row_return['Operational Allowance (TEU)'], errors='coerce')

    # Extract base freight rate from the CSV
    base_freight_rate_outbound = pd.to_numeric(row_outbound['Freight Rate per TEU'], errors='coerce')
    base_freight_rate_return = pd.to_numeric(row_return['Freight Rate per TEU'], errors='coerce')

    # Check if any values are missing or zero
    if pd.isna(total_full_teu_outbound) or pd.isna(total_full_teu_return) or total_full_teu_outbound == 0 or total_full_teu_return == 0:
        print(f"Skipping iteration due to missing or invalid TEU values: Outbound = {total_full_teu_outbound}, Return = {total_full_teu_return}")
        return pd.DataFrame()  # Return an empty DataFrame to skip this iteration

    if pd.isna(operational_allowance_outbound) or pd.isna(operational_allowance_return) or operational_allowance_outbound == 0 or operational_allowance_return == 0:
        print(f"Skipping iteration due to missing or invalid operational allowance")
        return pd.DataFrame()  # Return an empty DataFrame to skip this iteration

    # Set the bounds for the uniform distribution (20% decrease, 30% increase)
    min_freight_rate_outbound = base_freight_rate_outbound * 0.80  # 20% decrease
    max_freight_rate_outbound = base_freight_rate_outbound * 1.30  # 30% increase
    min_freight_rate_return = base_freight_rate_return * 0.80      # 20% decrease
    max_freight_rate_return = base_freight_rate_return * 1.30      # 30% increase

    # Freight rate distribution (uniform distribution)
    freight_rate_distribution_outbound = np.random.uniform(low=min_freight_rate_outbound, high=max_freight_rate_outbound, size=iterations)
    freight_rate_distribution_return = np.random.uniform(low=min_freight_rate_return, high=max_freight_rate_return, size=iterations)

    # Additional Empties for repositioning (uniform distribution)
    additional_empties_distribution_outbound = np.random.uniform(low=3600, high=35500, size=iterations)
    additional_empties_distribution_return = additional_empties_distribution_outbound*1

    # Transit times after random increase (5% to 30%)
    transit_time_increase_distribution_outbound = np.random.uniform(low=0.05, high=0.30, size=iterations)
    transit_time_increase_distribution_return = transit_time_increase_distribution_outbound*1


    # Perform the simulation for each pair of trips (outbound and return)
    for i in range(iterations):
```

```
freight_rate_outbound = freight_rate_distribution_outbound[i]
freight_rate_return = freight_rate_distribution_return[i]


# Transit times after random increase (5% to 30%)
transit_time_increase_outbound = transit_time_increase_distribution_outbound[i]
transit_time_increase_return = transit_time_increase_distribution_return[i]
#if i == 0:
    #print('freight_rate_outbound', 'freight_rate_return',  freight_rate_distribution_outbound, freight_rate_distribution_return)
    #print('')
    #print('additional_empties_outbound', 'additional_empties_return',  additional_empties_distribution_outbound, additional_empties_distribution_return)
    #print('')
    #print('transit_time_increase_outbound', 'transit_time_increase_return', transit_time_increase_distribution_outbound, transit_time_increase_distribution_return)
    #print('')

# Calculate new transit days after the increase
new_transit_days_outbound = current_transit_time_outbound * (1 + transit_time_increase_outbound)
new_transit_days_return = current_transit_time_return * (1 + transit_time_increase_return)

#print('Iteration %d' %i)
#print(f'Freight Rate (Outbound): {freight_rate_outbound:.2f} USD/TEU')
#print(f'Freight Rate (Return): {freight_rate_return:.2f} USD/TEU')
#print('new_transit_days_outbound', new_transit_days_outbound)
#print('new_transit_days_return', new_transit_days_return)

# Total revenue calculation (outbound and return)
total_revenue_outbound = total_full_teu_outbound * freight_rate_outbound
total_revenue_return = total_full_teu_return * freight_rate_return
#print('total_revenue_outbound', total_revenue_outbound)
#print('total_revenue_return', total_revenue_return)

# Total revenue per Day (outbound and return)
total_revenue_per_day_outbound = total_revenue_outbound / new_transit_days_outbound
total_revenue_per_day_return = total_revenue_return / new_transit_days_return
#print('total_revenue_per_day_outbound', total_revenue_per_day_outbound)
#print('total_revenue_per_day_return', total_revenue_per_day_return)

# Utilization Rate calculation
utilization_outbound = (total_full_teu_outbound + total_empty_teu_outbound + additional_empties_outbound) / operational_allowance_outbound
utilization_return = (total_full_teu_return + total_empty_teu_return + additional_empties_return) / operational_allowance_return
#print('utilization_outbound', utilization_outbound)
#print('utilization_return', utilization_return)

# Loss of revenue due to Repositioning (only for specific regions)
if row_outbound['Region'] in regions_with_loss_of_revenue:
    loss_of_revenue_due_to_repositioning_outbound = freight_rate_outbound * additional_empties_outbound
else:
    loss_of_revenue_due_to_repositioning_outbound = 0

if row_return['Region'] in regions_with_loss_of_revenue:
    loss_of_revenue_due_to_repositioning_return = freight_rate_return * additional_empties_return
else:
    loss_of_revenue_due_to_repositioning_return = 0

# Calculate the total loss of revenue per iteration
total_loss_of_revenue_due_to_repositioning_value = loss_of_revenue_due_to_repositioning_outbound + loss_of_revenue_due_to_repositioning_return

#print('loss_of_revenue_due_to_repositioning_outbound', loss_of_revenue_due_to_repositioning_outbound)
#print('loss_of_revenue_due_to_repositioning_return', loss_of_revenue_due_to_repositioning_return)


# Loss of revenue per Day (outbound and return)
if loss_of_revenue_due_to_repositioning_outbound == 0:
    loss_of_revenue_per_day_outbound = 0
else:
    loss_of_revenue_per_day_outbound = loss_of_revenue_due_to_repositioning_outbound / new_transit_days_outbound

if loss_of_revenue_due_to_repositioning_return == 0:
    loss_of_revenue_per_day_return = 0
else:
    loss_of_revenue_per_day_return = loss_of_revenue_due_to_repositioning_return / new_transit_days_return
#print('loss_of_revenue_per_day_outbound', loss_of_revenue_per_day_outbound)
#print('loss_of_revenue_per_day_return', loss_of_revenue_per_day_return)

# Total Revenue
total_revenue_outbound = (total_revenue_outbound + loss_of_revenue_due_to_repositioning_outbound)
total_revenue_return = (total_revenue_return + loss_of_revenue_due_to_repositioning_return)
total_revenue_value = (total_revenue_outbound + total_revenue_return)
#print('total_revenue_outbound', total_revenue_outbound)
#print('total_revenue_return', total_revenue_return)
#print('total_revenue_value', total_revenue_value)

# Total Revenue per Day
total_revenue_per_day_outbound = (total_revenue_per_day_outbound + loss_of_revenue_per_day_outbound)
total_revenue_per_day_return = (total_revenue_per_day_return + loss_of_revenue_per_day_return)
total_revenue_per_day_value = (total_revenue_per_day_outbound + total_revenue_per_day_return)
#print('total_revenue_per_day_outbound', total_revenue_per_day_outbound)
#print('total_revenue_per_day_return', total_revenue_per_day_return)
```

```
        #print('total_revenue_per_day_value', total_revenue_per_day_value)

        # Store results
        total_revenue.append(total_revenue_value)
        total_revenue_per_day.append(total_revenue_per_day_value)
        utilization_rate_outbound.append(utilization_outbound)
        utilization_rate_return.append(utilization_return)
        loss_of_revenue_per_day.append(loss_of_revenue_per_day_outbound + loss_of_revenue_per_day_return)
        total_loss_of_revenue_due_to_repositioning.append(total_loss_of_revenue_due_to_repositioning_value)

    # Return results for this region pair
    return pd.DataFrame({
        'Total Revenue': total_revenue,
        'Total Revenue per Day': total_revenue_per_day,
        'Utilization Rate Outbound': utilization_rate_outbound,
        'Utilization Rate Return': utilization_rate_return,
        'Freight Rate per TEU Outbound':freight_rate_outbound,
        'Freight Rate per TEU Return':freight_rate_return,
        'Average Transit Days Outbound':new_transit_days_outbound,
        'Average Transit Days Return':new_transit_days_return,
        'Additional Empties Outbound':additional_empties_outbound,
        'Additional Empties Return':additional_empties_return,
        'Loss of Revenue per Day': loss_of_revenue_per_day,
        'Total Loss of Revenue due to Repositioning': total_loss_of_revenue_due_to_repositioning
        })

# Function to handle the scenario logic for additional_empties based on the rules
def apply_additional_empties_scenarios(far_east_to_eu_outbound_value, scenario):
    additional_empties = {
        'EU to Africa': 0,
        'EU to Latin America': 0,
        'EU to North America': 0,
        'Africa to EU': 0,
        'Latin America to EU': 0,
        'North America to EU': 0,
        'Far East to EU': far_east_to_eu_outbound_value,  # Far East from to EU mirrors its outbound value
        'EU to Far East': far_east_to_eu_outbound_value  # EU to Far East gets the outbound value too
    }

    # Apply the scenario logic for outbound values
    if scenario == 1:
        additional_empties['EU to Africa'] = -far_east_to_eu_outbound_value
    elif scenario == 2:
        additional_empties['EU to Latin America'] = -far_east_to_eu_outbound_value
    elif scenario == 3:
        additional_empties['EU to North America'] = -far_east_to_eu_outbound_value
    elif scenario == 4:
        # This scenario distributes the negative value across the three regions
        total_split = -far_east_to_eu_outbound_value
        additional_empties['EU to Africa'] = total_split / 3
        additional_empties['EU to Latin America'] = total_split / 3
        additional_empties['EU to North America'] = total_split / 3

    return additional_empties

# Initialize dictionary to store results for all scenarios and regions
results = {scenario: {} for scenario in range(1, 5)}

# Main simulation process to handle the randomized values
for i in range(iterations):
    # Randomize the additional_empties_outbound for "Far East from to EU"
    additional_empties_outbound_far_east = np.random.uniform(low=3600, high=35500)

    # Define outbound and return trip pairs
    region_pairs = {
        'Far East from to EU': ('EU to Far East', 'Far East to EU'),
        'Africa from to EU': ('EU to Africa', 'Africa to EU'),
        'Latin America from to EU': ('EU to Latin America', 'Latin America to EU'),
        'North America from to EU': ('EU to North America', 'North America to EU')
    }

    # Process each of the four scenarios
    for scenario in range(1, 5):
        # Apply the scenario to determine the additional empties for other regions
        additional_empties = apply_additional_empties_scenarios(additional_empties_outbound_far_east, scenario)

        # Print results for verification of the logic (optional)
        #if i == 0:  # Just print the first iteration for verification
            #print(f"Iteration {i+1} - Processing all four scenarios")
            #print(f"Scenario {scenario} - EU to Far East Outbound: {additional_empties_outbound_far_east}")
            #print(f"Additional Empties Assigned per Route (for Scenario {scenario}):")
            #for route, value in additional_empties.items():
                #print(f"{route}: {value}")

        # Process each pair of regions for this scenario
        for region_pair, (outbound, return_trip) in region_pairs.items():
            # Ensure the data filtering returns a non-empty DataFrame
            row_outbound = data[data['Region'] == outbound]
```

```
        row_return = data[data['Region'] == return_trip]

        #print(f"Outbound: {outbound}, Return: {return_trip}")
        #print(f"Row Outbound: {row_outbound}")
        #print(f"Row Return: {row_return}")

        if row_outbound.empty or row_return.empty:
            #print(f"Skipping region pair {region_pair} due to missing data")
            continue

        # Access the first row of filtered results
        row_outbound = row_outbound.iloc[0]
        row_return = row_return.iloc[0]

        # Pass the specific additional empties value from the scenario logic
        additional_empties_outbound = additional_empties[outbound]
        additional_empties_return = additional_empties[return_trip]

        # Perform the region revenue calculation
        result_df = calculate_revenue_for_region(row_outbound, row_return, additional_empties_outbound, additional_empties_return)

        # Store the results for this scenario and region pair
        if region_pair not in results[scenario]:
            results[scenario][region_pair] = result_df
        else:
            results[scenario][region_pair] = pd.concat([results[scenario][region_pair], result_df], ignore_index=True)

# Adjusted Total Revenue Calculation for 'Far East from to EU'
for scenario in range(1, 5):
    #print(f"Available keys for scenario {scenario}: {list(results[scenario].keys())}")  # Add this line to check available keys
    if 'Far East from to EU' not in results[scenario]:
        #print(f"'Far East from to EU' key not found in scenario {scenario}, skipping")
        continue  # Skip this scenario if the key doesn't exist

    far_east_from_to_eu = results[scenario]['Far East from to EU']

    if scenario == 1:
        eu_to_africa = results[scenario]['Africa from to EU']
        far_east_from_to_eu['Adjusted Total Revenue'] = far_east_from_to_eu['Total Revenue'] + eu_to_africa['Total Loss of Revenue due to Repositioning']
        far_east_from_to_eu['Adjusted Total Revenue per Day'] = far_east_from_to_eu['Total Revenue per Day'] + eu_to_africa['Loss of Revenue per Day']
    elif scenario == 2:
        eu_to_latin_america = results[scenario]['Latin America from to EU']
        far_east_from_to_eu['Adjusted Total Revenue'] = far_east_from_to_eu['Total Revenue'] + eu_to_latin_america['Total Loss of Revenue due to Repositioning']
        far_east_from_to_eu['Adjusted Total Revenue per Day'] = far_east_from_to_eu['Total Revenue per Day'] + eu_to_latin_america['Loss of Revenue per Day']
    elif scenario == 3:
        eu_to_north_america = results[scenario]['North America from to EU']
        far_east_from_to_eu['Adjusted Total Revenue'] = far_east_from_to_eu['Total Revenue'] + eu_to_north_america['Total Loss of Revenue due to Repositioning']
        far_east_from_to_eu['Adjusted Total Revenue per Day'] = far_east_from_to_eu['Total Revenue per Day'] + eu_to_north_america['Loss of Revenue per Day']
    elif scenario == 4:
        eu_to_africa = results[scenario]['Africa from to EU']
        eu_to_latin_america = results[scenario]['Latin America from to EU']
        eu_to_north_america = results[scenario]['North America from to EU']
        far_east_from_to_eu['Adjusted Total Revenue'] = (far_east_from_to_eu['Total Revenue'] + eu_to_africa['Total Loss of Revenue due to Repositioning'] +
                                                         eu_to_latin_america['Total Loss of Revenue due to Repositioning'] +
                                                         eu_to_north_america['Total Loss of Revenue due to Repositioning'])
        far_east_from_to_eu['Adjusted Total Revenue per Day'] = (far_east_from_to_eu['Total Revenue per Day'] + eu_to_africa['Loss of Revenue per Day'] +
                                                                 eu_to_latin_america['Loss of Revenue per Day'] +
                                                                 eu_to_north_america['Loss of Revenue per Day'])

# Analyze results for each region pair and scenario
for scenario in range(1, 5):
    print(f"Summary for Scenario {scenario}:")
    for region_name, result_df in results[scenario].items():
        print(f"Summary for {region_name} (Scenario {scenario})")
        print(result_df.describe())
        print("\n")
import seaborn as sns
import pandas as pd
import matplotlib.pyplot as plt

# Create a new DataFrame to store all the data for visualization
df_all_scenarios = pd.DataFrame()

# Loop through each scenario and region and prepare the data
regions = ['Far East from to EU', 'Africa from to EU', 'Latin America from to EU', 'North America from to EU']
scenarios = [1, 2, 3, 4]

for scenario in scenarios:
    for region in regions:
        temp_df = results[scenario][region].copy()  # Copy the data for that region in that scenario
        temp_df['Region'] = region  # Add a column for region
        temp_df['Scenario'] = f'Scenario {scenario}'  # Add a column for scenario
        df_all_scenarios = pd.concat([df_all_scenarios, temp_df], ignore_index=True)  # Concatenate data

# Create the facet grid for visualization
g = sns.FacetGrid(df_all_scenarios, col="Region", row="Scenario", height=4, aspect=1.5, sharex=True)
g.map(sns.histplot, "Total Revenue per Day", kde=False, color='skyblue', edgecolor='black')  # Add histogram styling
```

```
# Add global axis labels
g.set_axis_labels("Total Revenue per Day", "Frequency")
g.set_ylabels("Frequency", fontsize=16, color="black")
for ax in g.axes.flat:
    ax.set_xlabel("Total Revenue per Day", fontsize=14, color="black")


# Ensure all x-axis tick labels are shown for each subplot
for ax in g.axes.flat:
    ax.tick_params(axis='x', which='both', labelbottom=True)  # Enable x-axis labels for all subplots

# Customize tick labels and rotation
for ax in g.axes.flat:
    ax.tick_params(axis='x', labelsize=14, labelcolor='black', rotation=45)
    ax.tick_params(axis='y', labelsize=14, labelcolor='black')
    # Set x and y tick labels to bold
    for tick in ax.get_xticklabels():
        tick.set_fontweight("bold")
    for tick in ax.get_yticklabels():
        tick.set_fontweight("bold")

# Simplify subplot titles
for ax in g.axes.flat:
    ax.set_title(ax.get_title().replace("Scenario = ", "").replace("Region = ", ""), fontsize=16, color="black")

# Add the overall title
g.fig.suptitle("Distribution of Total Revenue per Day Across Regions and Scenarios", y=1.05, fontsize=20, color="black")

# Adjust spacing between subplots
plt.subplots_adjust(hspace=0.5, wspace=0.3)

# Adjust figure size for better clarity
g.fig.set_size_inches(20, 14)

# Show the plot
plt.show()

import seaborn as sns
import pandas as pd
import matplotlib.pyplot as plt

# Create a new DataFrame to store all the data for visualization
df_all_scenarios = pd.DataFrame()

# Loop through each scenario and region and prepare the data
regions = ['Far East from to EU', 'Africa from to EU', 'Latin America from to EU', 'North America from to EU']
scenarios = [1, 2, 3, 4]

for scenario in scenarios:
    for region in regions:
        temp_df = results[scenario][region].copy()  # Copy the data for that region in that scenario
        temp_df['Region'] = region  # Add a column for region
        temp_df['Scenario'] = f'Scenario {scenario}'  # Add a column for scenario
        df_all_scenarios = pd.concat([df_all_scenarios, temp_df], ignore_index=True)  # Concatenate data

# Create the facet grid for visualization
g = sns.FacetGrid(df_all_scenarios, col="Region", row="Scenario", height=4, aspect=1.5, sharex=True)
g.map(sns.histplot, "Total Revenue", kde=False, color='skyblue', edgecolor='black')  # Add histogram styling

# Add global axis labels
g.set_axis_labels("Total Revenue", "Frequency")
g.set_ylabels("Frequency", fontsize=16, color="black")
for ax in g.axes.flat:
    ax.set_xlabel("Total Revenue", fontsize=18, color="black")

# Ensure all x-axis tick labels are shown for each subplot
for ax in g.axes.flat:
    ax.tick_params(axis='x', which='both', labelbottom=True)  # Enable x-axis labels for all subplots

# Customize tick labels and rotation
for ax in g.axes.flat:
    ax.tick_params(axis='x', labelsize=16, labelcolor='black', rotation=45)
    ax.tick_params(axis='y', labelsize=14, labelcolor='black')
    # Set x and y tick labels to bold
    for tick in ax.get_xticklabels():
        tick.set_fontweight("bold")
    for tick in ax.get_yticklabels():
        tick.set_fontweight("bold")

# Simplify subplot titles
for ax in g.axes.flat:
    ax.set_title(ax.get_title().replace("Scenario = ", "").replace("Region = ", ""), fontsize=16, color="black")

# Add the overall title
g.fig.suptitle("Distribution of Total Revenue Across Regions and Scenarios", y=1.05, fontsize=20, color="black")

# Adjust spacing between subplots
plt.subplots_adjust(hspace=0.5, wspace=0.3)
```

```
# Adjust figure size for better clarity
g.fig.set_size_inches(20, 14)

# Show the plot
plt.show()
import seaborn as sns
import pandas as pd
import matplotlib.pyplot as plt

# Create a new DataFrame to store all the data for visualization
df_all_scenarios = pd.DataFrame()

# Loop through each scenario and region and prepare the data
regions = ['Far East from to EU', 'Africa from to EU', 'Latin America from to EU', 'North America from to EU']
scenarios = [1, 2, 3, 4]

for scenario in scenarios:
    for region in regions:
        temp_df = results[scenario][region].copy()  # Copy the data for that region in that scenario
        temp_df['Region'] = region  # Add a column for region
        temp_df['Scenario'] = f'Scenario {scenario}'  # Add a column for scenario
        df_all_scenarios = pd.concat([df_all_scenarios, temp_df], ignore_index=True)  # Concatenate data

# Create the facet grid for visualization
g = sns.FacetGrid(df_all_scenarios, col="Region", row="Scenario", height=6, aspect=2, sharex=False, sharey=False)
g.map(sns.histplot, "Utilization Rate Outbound", kde=False, color='skyblue', edgecolor='black', bins=20)  # Reduced bins for clarity

# Adjust x-axis and y-axis limits for specific subplots
for ax, (scenario, region) in zip(g.axes.flat, df_all_scenarios.groupby(['Scenario', 'Region']).groups):
    if region == 'Far East from to EU' or region == 'Africa from to EU':
        ax.set_ylim(0, 250000)  # Custom Y-axis limit for better visibility
        ax.set_xlim(0.5, 1.08)  # Custom X-axis range
    elif region == 'Latin America from to EU' or region == 'North America from to EU':
        ax.set_ylim(0, 250000)  # General Y-axis limit for dense data
        ax.set_xlim(0.5, 1.08)

# Add global axis labels
g.set_axis_labels("Utilization Rate Outbound", "Frequency")
g.set_ylabels("Frequency", fontsize=16, color="black")
for ax in g.axes.flat:
    ax.set_xlabel("Utilization Rate Outbound", fontsize=18, color="black")

# Ensure all x-axis tick labels are shown for each subplot
for ax in g.axes.flat:
    ax.tick_params(axis='x', which='both', labelbottom=True)  # Enable x-axis labels for all subplots

# Customize tick labels, rotation, and bold font
for ax in g.axes.flat:
    ax.tick_params(axis='x', labelsize=16, labelcolor='black', rotation=45)
    ax.tick_params(axis='y', labelsize=14, labelcolor='black')
    # Set x and y tick labels to bold
    for tick in ax.get_xticklabels():
        tick.set_fontweight("bold")
    for tick in ax.get_yticklabels():
        tick.set_fontweight("bold")

# Simplify subplot titles
for ax in g.axes.flat:
    ax.set_title(ax.get_title().replace("Scenario = ", "").replace("Region = ", ""), fontsize=16, color="black")

# Add the overall title
g.fig.suptitle("Distribution of Utilization Rate Outbound Across Regions and Scenarios", y=1.02, fontsize=20, color="black")

# Adjust spacing between subplots
plt.subplots_adjust(hspace=0.6, wspace=0.4)

# Adjust figure size for better clarity
g.fig.set_size_inches(30, 20)  # Increased figure size for better visibility

# Show the plot
plt.show()

import seaborn as sns
import pandas as pd
import matplotlib.pyplot as plt

# Create a new DataFrame to store all the data for visualization
df_all_scenarios = pd.DataFrame()

# Loop through each scenario and region and prepare the data
regions = ['Far East from to EU', 'Africa from to EU', 'Latin America from to EU', 'North America from to EU']
scenarios = [1, 2, 3, 4]

for scenario in scenarios:
    for region in regions:
        temp_df = results[scenario][region].copy()  # Copy the data for that region in that scenario
        temp_df['Region'] = region  # Add a column for region
```

```
        temp_df['Scenario'] = f'Scenario {scenario}'  # Add a column for scenario
        df_all_scenarios = pd.concat([df_all_scenarios, temp_df], ignore_index=True)  # Concatenate data

# Create the facet grid for visualization
g = sns.FacetGrid(df_all_scenarios, col="Region", row="Scenario", height=6, aspect=2, sharex=False, sharey=False)
g.map(sns.histplot, "Utilization Rate Return", kde=False, color='skyblue', edgecolor='black', bins=20)  # Reduced bins for clarity

# Adjust x-axis and y-axis limits for specific subplots
for ax, (scenario, region) in zip(g.axes.flat, df_all_scenarios.groupby(['Scenario', 'Region']).groups):
    if region == 'Far East from to EU' or region == 'Africa from to EU':
        ax.set_ylim(0, 250000)  # Custom Y-axis limit for better visibility
        ax.set_xlim(0.6, 1.08)  # Custom X-axis range
    elif region == 'Latin America from to EU' or region == 'North America from to EU':
        ax.set_ylim(0, 250000)  # General Y-axis limit for dense data
        ax.set_xlim(0.5, 1.08)

# Add global axis labels
g.set_axis_labels("Utilization Rate Return", "Frequency")
g.set_ylabels("Frequency", fontsize=16, color="black")
for ax in g.axes.flat:
    ax.set_xlabel("Utilization Rate Return", fontsize=18, color="black")

# Ensure all x-axis tick labels are shown for each subplot
for ax in g.axes.flat:
    ax.tick_params(axis='x', which='both', labelbottom=True)  # Enable x-axis labels for all subplots

# Customize tick labels, rotation, and bold font
for ax in g.axes.flat:
    ax.tick_params(axis='x', labelsize=16, labelcolor='black', rotation=45)
    ax.tick_params(axis='y', labelsize=14, labelcolor='black')
    # Set x and y tick labels to bold
    for tick in ax.get_xticklabels():
        tick.set_fontweight("bold")
    for tick in ax.get_yticklabels():
        tick.set_fontweight("bold")

# Simplify subplot titles
for ax in g.axes.flat:
    ax.set_title(ax.get_title().replace("Scenario = ", "").replace("Region = ", ""), fontsize=16, color="black")

# Add the overall title
g.fig.suptitle("Distribution of Utilization Rate Return Across Regions and Scenarios", y=1.02, fontsize=20, color="black")

# Adjust spacing between subplots
plt.subplots_adjust(hspace=0.6, wspace=0.4)

# Adjust figure size for better clarity
g.fig.set_size_inches(30, 20)  # Increased figure size for better visibility

# Show the plot
plt.show()

import seaborn as sns
import pandas as pd
import matplotlib.pyplot as plt

# Create a new DataFrame to store all the data for visualization
df_all_scenarios = pd.DataFrame()

# Loop through each scenario and region and prepare the data
regions = ['Far East from to EU', 'Africa from to EU', 'Latin America from to EU', 'North America from to EU']
scenarios = [1, 2, 3, 4]

for scenario in scenarios:
    for region in regions:
        temp_df = results[scenario][region].copy()  # Copy the data for that region in that scenario
        temp_df['Region'] = region  # Add a column for region
        temp_df['Scenario'] = f'Scenario {scenario}'  # Add a column for scenario
        df_all_scenarios = pd.concat([df_all_scenarios, temp_df], ignore_index=True)  # Concatenate data

# Create the facet grid for visualization
g = sns.FacetGrid(df_all_scenarios, col="Region", row="Scenario", height=6, aspect=2, sharex=False, sharey=False)
g.map(sns.histplot, "Loss of Revenue per Day", kde=False, color='skyblue', edgecolor='black', bins=20)  # Reduced bins for clarity

# Adjust x-axis and y-axis limits for specific subplots
for ax, (scenario, region) in zip(g.axes.flat, df_all_scenarios.groupby(['Scenario', 'Region']).groups):
    if region == 'Far East from to EU' or region == 'Africa from to EU':
        ax.set_ylim(0, 50000)  # Custom Y-axis limit for better visibility
        ax.set_xlim(-3e6, 3e6)  # Custom X-axis range for sparse data
    elif region == 'Latin America from to EU' or region == 'North America from to EU':
        ax.set_ylim(0, 50000)  # General Y-axis limit for dense data
        ax.set_xlim(-5e6, 2e6)

# Add global axis labels
g.set_axis_labels("Loss of Revenue per Day", "Frequency")
g.set_ylabels("Frequency", fontsize=16, color="black")
for ax in g.axes.flat:
    ax.set_xlabel("Loss of Revenue per Day", fontsize=18, color="black")
```

```
# Ensure all x-axis tick labels are shown for each subplot
for ax in g.axes.flat:
    ax.tick_params(axis='x', which='both', labelbottom=True)  # Enable x-axis labels for all subplots

# Customize tick labels, rotation, and bold font
for ax in g.axes.flat:
    ax.tick_params(axis='x', labelsize=16, labelcolor='black', rotation=45)
    ax.tick_params(axis='y', labelsize=14, labelcolor='black')
    # Set x and y tick labels to bold
    for tick in ax.get_xticklabels():
        tick.set_fontweight("bold")
    for tick in ax.get_yticklabels():
        tick.set_fontweight("bold")

# Simplify subplot titles
for ax in g.axes.flat:
    ax.set_title(ax.get_title().replace("Scenario = ", "").replace("Region = ", ""), fontsize=16, color="black")

# Add the overall title
g.fig.suptitle("Distribution of Loss of Revenue per Day Across Regions and Scenarios", y=1.02, fontsize=20, color="black")

# Adjust spacing between subplots
plt.subplots_adjust(hspace=0.6, wspace=0.4)

# Adjust figure size for better clarity
g.fig.set_size_inches(30, 20)  # Increased figure size for better visibility

# Show the plot
plt.show()

import seaborn as sns
import pandas as pd
import matplotlib.pyplot as plt

# Create a new DataFrame to store all the data for visualization
df_all_scenarios = pd.DataFrame()

# Loop through each scenario and region and prepare the data
regions = ['Far East from to EU', 'Africa from to EU', 'Latin America from to EU', 'North America from to EU']
scenarios = [1, 2, 3, 4]

for scenario in scenarios:
    for region in regions:
        temp_df = results[scenario][region].copy()  # Copy the data for that region in that scenario
        temp_df['Region'] = region  # Add a column for region
        temp_df['Scenario'] = f'Scenario {scenario}'  # Add a column for scenario
        df_all_scenarios = pd.concat([df_all_scenarios, temp_df], ignore_index=True)  # Concatenate data

# Create the facet grid for visualization
g = sns.FacetGrid(df_all_scenarios, col="Region", row="Scenario", height=6, aspect=2, sharex=False, sharey=False)
g.map(sns.histplot, "Total Loss of Revenue due to Repositioning", kde=False, color='skyblue', edgecolor='black', bins=20)  # Reduced bins for clarity

# Adjust x-axis and y-axis limits for specific subplots
for ax, (scenario, region) in zip(g.axes.flat, df_all_scenarios.groupby(['Scenario', 'Region']).groups):
    if region == 'Far East from to EU' or region == 'Africa from to EU':
        ax.set_ylim(0, 50000)  # Custom Y-axis limit for better visibility
        ax.set_xlim(-1e8, 2e8)  # Custom X-axis range for sparse data
    elif region == 'Latin America from to EU' or region == 'North America from to EU':
        ax.set_ylim(0, 50000)  # General Y-axis limit for dense data
        ax.set_xlim(-1e8, 1e8)

# Add global axis labels
g.set_axis_labels("Total Loss of Revenue due to Repositioning", "Frequency")
g.set_ylabels("Frequency", fontsize=16, color="black")
for ax in g.axes.flat:
    ax.set_xlabel("Total Loss of Revenue due to Repositioning", fontsize=18, color="black")

# Ensure all x-axis tick labels are shown for each subplot
for ax in g.axes.flat:
    ax.tick_params(axis='x', which='both', labelbottom=True)  # Enable x-axis labels for all subplots

# Customize tick labels, rotation, and bold font
for ax in g.axes.flat:
    ax.tick_params(axis='x', labelsize=16, labelcolor='black', rotation=45)
    ax.tick_params(axis='y', labelsize=14, labelcolor='black')
    # Set x and y tick labels to bold
    for tick in ax.get_xticklabels():
        tick.set_fontweight("bold")
    for tick in ax.get_yticklabels():
        tick.set_fontweight("bold")

# Simplify subplot titles
for ax in g.axes.flat:
    ax.set_title(ax.get_title().replace("Scenario = ", "").replace("Region = ", ""), fontsize=16, color="black")

# Add the overall title
g.fig.suptitle("Distribution of Total Loss of Revenue due to Repositioning Across Regions and Scenarios", y=1.02, fontsize=20, color="black")
```

```
# Adjust spacing between subplots
plt.subplots_adjust(hspace=0.6, wspace=0.4)

# Adjust figure size for better clarity
g.fig.set_size_inches(30, 20)  # Increased figure size for better visibility

# Show the plot
plt.show()

import numpy as np
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt

# Initialize an empty DataFrame to store the combined data from all scenarios
combined_data = pd.DataFrame()

# Loop through all scenarios and regions to aggregate data
for scenario in range(1, 5):
    for region in ['Far East from to EU', 'Africa from to EU', 'Latin America from to EU', 'North America from to EU']:
        if region in results[scenario]:
            region_data = results[scenario][region].copy()
            region_data['Scenario'] = scenario  # Add scenario identifier
            region_data['Region'] = region      # Add region identifier
            combined_data = pd.concat([combined_data, region_data], ignore_index=True)

# Select the relevant columns for correlation analysis
columns_for_corr = ['Freight Rate per TEU Outbound', 'Freight Rate per TEU Return', 'Utilization Rate Outbound',
                    'Utilization Rate Return', 'Average Transit Days Outbound',
                    'Average Transit Days Return', 'Total Revenue', 'Total Revenue per Day']

# Filter the combined data for these columns
df_for_correlation = combined_data[columns_for_corr]

# Calculate the correlation matrix
correlation_matrix = df_for_correlation.corr()

# Function to determine font color based on cell value
def get_text_color(value, cmap, vmin, vmax):
    norm = plt.Normalize(vmin, vmax)  # Normalize the data to colormap range
    rgba = cmap(norm(value))  # Get RGBA color for the value
    r, g, b, _ = rgba  # Extract RGB values
    brightness = r * 0.299 + g * 0.587 + b * 0.114  # Calculate perceived brightness
    return "white" if brightness < 0.5 else "black"  # White text for dark background

# Create the heatmap
plt.figure(figsize=(15, 12))
cmap = plt.cm.viridis  # Choose a colormap
sns.heatmap(
    correlation_matrix,
    annot=False,  # Turn off annotations in sns.heatmap
    cmap=cmap,
    linewidths=0.5,
    square=True
)

# Add custom annotations
vmin, vmax = correlation_matrix.min().min(), correlation_matrix.max().max()
for i in range(correlation_matrix.shape[0]):
    for j in range(correlation_matrix.shape[1]):
        value = correlation_matrix.iloc[i, j]
        text_color = get_text_color(value, cmap, vmin, vmax)  # Determine text color
        plt.text(
            j + 0.5, i + 0.5,  # Adjust position
            f"{value:.2f}",  # Format the text
            ha="center", va="center", color=text_color, fontsize=15, fontweight="bold"
        )

# Customize titles and labels
plt.xticks(fontsize=14, rotation=90, fontweight="bold")
plt.yticks(fontsize=14, rotation=0, fontweight="bold")
plt.title("Correlation Heatmap Across All Scenarios and Regions", fontsize=16, color="black", fontweight="bold")

# Save or show the plot
plt.savefig('heatmap_across_scenarios_regions.png', dpi=800, bbox_inches='tight')  # Save with high resolution
plt.show()

import numpy as np
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt

# Initialize an empty DataFrame to store the combined data from all scenarios
combined_data = pd.DataFrame()

# Loop through all scenarios and regions to aggregate data
for scenario in range(1, 5):
```

```
    for region in ['Far East from to EU', 'Africa from to EU', 'Latin America from to EU', 'North America from to EU']:
        if region in results[scenario]:
            region_data = results[scenario][region].copy()
            region_data['Scenario'] = scenario  # Add scenario identifier
            region_data['Region'] = region      # Add region identifier
            combined_data = pd.concat([combined_data, region_data], ignore_index=True)

# Select the relevant columns for correlation analysis
columns_for_corr = ['Freight Rate per TEU Outbound', 'Freight Rate per TEU Return', 'Utilization Rate Outbound',
                    'Utilization Rate Return', 'Average Transit Days Outbound',
                    'Average Transit Days Return', 'Total Revenue', 'Total Revenue per Day']

# Function to determine font color based on cell value
def get_text_color(value, cmap, vmin, vmax):
    norm = plt.Normalize(vmin, vmax)  # Normalize the data to colormap range
    rgba = cmap(norm(value))  # Get RGBA color for the value
    r, g, b, _ = rgba  # Extract RGB values
    brightness = r * 0.299 + g * 0.587 + b * 0.114  # Calculate perceived brightness
    return "white" if brightness < 0.5 else "black"  # White text for dark background

# Loop through each region and calculate the correlation for that specific region
for region in ['Far East from to EU', 'Africa from to EU', 'Latin America from to EU', 'North America from to EU']:

    # Filter the combined data for the current region
    region_data = combined_data[combined_data['Region'] == region]

    # Check if the region has data
    if region_data.empty:
        print(f"No data available for region: {region}")
        continue

    # Filter the data for the relevant columns
    df_for_correlation = region_data[columns_for_corr]

    # Calculate the correlation matrix for the region
    correlation_matrix = df_for_correlation.corr()

    # Plot the correlation heatmap with dynamic font colors
    plt.figure(figsize=(15, 12))
    cmap = plt.cm.viridis  # Choose a colormap
    sns.heatmap(
        correlation_matrix,
        annot=False,  # Turn off default annotations
        cmap=cmap,
        linewidths=0.5,
        square=True
    )

    # Add custom annotations with dynamic font colors
    vmin, vmax = correlation_matrix.min().min(), correlation_matrix.max().max()
    for i in range(correlation_matrix.shape[0]):
        for j in range(correlation_matrix.shape[1]):
            value = correlation_matrix.iloc[i, j]
            text_color = get_text_color(value, cmap, vmin, vmax)  # Determine text color
            plt.text(
                j + 0.5, i + 0.5,  # Adjust position
                f"{value:.2f}",  # Format the text
                ha="center", va="center", color=text_color, fontsize=15, fontweight="bold"
            )

    # Customize titles and labels
    plt.xticks(fontsize=14, rotation=90, fontweight="bold")
    plt.yticks(fontsize=14, rotation=0, fontweight="bold")
    plt.title(f'Correlation Heatmap for {region}', fontsize=16, color="black", fontweight="bold")

    # Save or show the plot
    plt.savefig(f'heatmap_{region.replace(" ", "_").lower()}.png', dpi=800, bbox_inches='tight')  # Save with high resolution
    plt.show()

import numpy as np
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt

# Initialize an empty DataFrame to store the combined data from all scenarios
combined_data = pd.DataFrame()

# Loop through all scenarios and regions to aggregate data
for scenario in range(1, 5):
    for region in ['Far East from to EU', 'Africa from to EU', 'Latin America from to EU', 'North America from to EU']:
        if region in results[scenario]:
            region_data = results[scenario][region].copy()
            region_data['Scenario'] = scenario  # Add scenario identifier
            region_data['Region'] = region      # Add region identifier
            combined_data = pd.concat([combined_data, region_data], ignore_index=True)

# Select the relevant columns for correlation analysis
columns_for_corr = [
```

```
    'Freight Rate per TEU Outbound', 'Freight Rate per TEU Return', 'Utilization Rate Outbound',
    'Additional Empties Outbound', 'Additional Empties Return',
    'Utilization Rate Return', 'Average Transit Days Outbound',
    'Average Transit Days Return', 'Total Revenue', 'Total Revenue per Day'
]

# Function to determine font color based on cell value
def get_text_color(value, cmap, vmin, vmax):
    norm = plt.Normalize(vmin, vmax)  # Normalize the data to colormap range
    rgba = cmap(norm(value))  # Get RGBA color for the value
    r, g, b, _ = rgba  # Extract RGB values
    brightness = r * 0.299 + g * 0.587 + b * 0.114  # Calculate perceived brightness
    return "white" if brightness < 0.5 else "black"  # White text for dark background

# Loop through each region and calculate the correlation for that specific region
for region in ['Far East from to EU', 'Africa from to EU', 'Latin America from to EU', 'North America from to EU']:

    # Filter the combined data for the current region
    region_data = combined_data[combined_data['Region'] == region]

    # Check if the region has data
    if region_data.empty:
        print(f"No data available for region: {region}")
        continue

    # Filter the data for the relevant columns
    df_for_correlation = region_data[columns_for_corr]

    # Calculate the correlation matrix for the region
    correlation_matrix = df_for_correlation.corr()

    # Plot the correlation heatmap with dynamic font colors
    plt.figure(figsize=(15, 12))
    cmap = plt.cm.viridis  # Use a visually appealing colormap
    sns.heatmap(
        correlation_matrix,
        annot=False,  # Turn off default annotations
        cmap=cmap,
        linewidths=0.5,
        square=True
    )

    # Add custom annotations with dynamic font colors
    vmin, vmax = correlation_matrix.min().min(), correlation_matrix.max().max()
    for i in range(correlation_matrix.shape[0]):
        for j in range(correlation_matrix.shape[1]):
            value = correlation_matrix.iloc[i, j]
            text_color = get_text_color(value, cmap, vmin, vmax)  # Determine text color
            plt.text(
                j + 0.5, i + 0.5,  # Adjust position
                f"{value:.2f}",  # Format the text
                ha="center", va="center", color=text_color, fontsize=15, fontweight="bold"
            )

    # Customize titles and labels
    plt.xticks(fontsize=14, rotation=90, fontweight="bold")
    plt.yticks(fontsize=14, rotation=0, fontweight="bold")
    plt.title(f'Correlation Heatmap for {region}', fontsize=16, color="black", fontweight="bold")

    # Save or show the plot
    plt.savefig(f'heatmap_{region.replace(" ", "_").lower()}.png', dpi=800, bbox_inches='tight')  # Save as high-res file
    plt.show()

import matplotlib.pyplot as plt

# Iterate through each scenario
for scenario in range(1, 5):  # Assuming scenarios are numbered from 1 to 4
    # Initialize a new figure for each scenario
    plt.figure(figsize=(10, 6))

    # Access the results for this scenario
    scenario_results = results[scenario]

    # Plot for each region in this scenario
    for region_name, region_data in scenario_results.items():
        plt.plot(region_data['Additional Empties Outbound'],
                 region_data['Total Revenue'],
                 label=region_name)

    # Add labels, title, and legend
    plt.xlabel('Additional Empties Outbound (TEU)')
    plt.ylabel('Total Revenue (USD)')
    plt.title(f'Total Revenue vs Additional Empties Outbound (Scenario {scenario})')
    plt.legend()

    # Adjust layout and show the plot
    plt.tight_layout()
    plt.show()
```

Appendix I

Phyton Script for Alternative 2 (With Seasonality)

```
import numpy as np
import pandas as pd

# Dictionary to store the results for each month
processed_months = set()
monthly_results = {}

for i_month in range(1, 13):
   print(f"Processing Month {i_month}")  # Debug statement to track execution

   # Load data files using the original Windows file path format
   csv_path = r"C:\Users\tinez\OneDrive - Delft University of Technology\Thesis\Thesis Proposal Part 2\Per Month_Seasonality\Month_%d.csv" % i_month #Replace with the actual path to your CSV file
   var_csv_path = r"C:\Users\tinez\OneDrive - Delft University of Technology\Thesis\Thesis Proposal Part 2\Per Month_Seasonality\Var_Month_%d.csv" % i_month #Replace with the actual path to your 
CSV file

   try:
      data = pd.read_csv(csv_path)
      data_var = pd.read_csv(var_csv_path)
   except FileNotFoundError:
      print(f"Missing data for Month {i_month}, skipping.")
      continue

   # Number of simulations
   iterations = 500

   # Regions where "Loss of Revenue due to Repositioning" applies
   regions_with_loss_of_revenue = [
      "Far East to EU",
      "EU to Africa",
      "EU to Latin America",
      "EU to North America"
   ]

   # Initialize dictionary to store results for all regions
   results = {scenario: {} for scenario in range(1, 5)}

   # Helper function to calculate revenue and losses for the region pair
   def calculate_revenue_for_region(row_outbound, row_return, additional_empties_outbound, additional_empties_return, min_freight_rate_outbound,max_freight_rate_outbound, 
min_freight_rate_return, max_freight_rate_return):

      #print(row_outbound['Region'])
      #print(row_return['Region'])
      total_revenue = []
      total_revenue_per_day = []
      utilization_rate_outbound = []
      utilization_rate_return = []
      loss_of_revenue_per_day = []
      total_loss_of_revenue_due_to_repositioning = []

      # Convert the Total Full TEU to numeric (in case it's stored as a string in the CSV)
      total_full_teu_outbound = pd.to_numeric(row_outbound['Total Full TEU'], errors='coerce')
      total_full_teu_return = pd.to_numeric(row_return['Total Full TEU'], errors='coerce')

      total_empty_teu_outbound = pd.to_numeric(row_outbound['Total Empty TEU'], errors='coerce')
      total_empty_teu_return = pd.to_numeric(row_return['Total Empty TEU'], errors='coerce')

      current_transit_time_outbound = pd.to_numeric(row_outbound['Average Transit Days'], errors='coerce')
      current_transit_time_return = pd.to_numeric(row_return['Average Transit Days'], errors='coerce')

      operational_allowance_outbound = pd.to_numeric(row_outbound['Operational Allowance (TEU)'], errors='coerce')
      operational_allowance_return = pd.to_numeric(row_return['Operational Allowance (TEU)'], errors='coerce')

      # Extract base freight rate from the CSV
      base_freight_rate_outbound = pd.to_numeric(row_outbound['Freight Rate per TEU'], errors='coerce')
      base_freight_rate_return = pd.to_numeric(row_return['Freight Rate per TEU'], errors='coerce')

      # Check if any values are missing or zero
      if pd.isna(total_full_teu_outbound) or pd.isna(total_full_teu_return) or total_full_teu_outbound == 0 or total_full_teu_return == 0:
         print(f"Skipping iteration due to missing or invalid TEU values: Outbound = {total_full_teu_outbound}, Return = {total_full_teu_return}")
         return pd.DataFrame()  # Return an empty DataFrame to skip this iteration

      if pd.isna(operational_allowance_outbound) or pd.isna(operational_allowance_return) or operational_allowance_outbound == 0 or operational_allowance_return == 0:
         print(f"Skipping iteration due to missing or invalid operational allowance")
         return pd.DataFrame()  # Return an empty DataFrame to skip this iteration

      # Freight rate distribution (uniform distribution)
      freight_rate_distribution_outbound = np.random.uniform(low=min_freight_rate_outbound, high=max_freight_rate_outbound, size=iterations)
      freight_rate_distribution_return = np.random.uniform(low=min_freight_rate_return, high=max_freight_rate_return, size=iterations)

      # Transit times after random increase (5% to 30%)
      transit_time_increase_distribution_outbound = np.random.uniform(low=0.05, high=0.30, size=iterations)
```

```
transit_time_increase_distribution_return = transit_time_increase_distribution_outbound*1


# Perform the simulation for each pair of trips (outbound and return)
for i in range(iterations):
    freight_rate_outbound = freight_rate_distribution_outbound[i]
    freight_rate_return = freight_rate_distribution_return[i]


    # Transit times after random increase (5% to 30%)
    transit_time_increase_outbound = transit_time_increase_distribution_outbound[i]
    transit_time_increase_return = transit_time_increase_distribution_return[i]
    #if i == 0:
        #print('freight_rate_outbound', 'freight_rate_return',  freight_rate_distribution_outbound, freight_rate_distribution_return)
        #print('')
        #print('additional_empties_outbound', 'additional_empties_return',  additional_empties_distribution_outbound, additional_empties_distribution_return)
        #print('')
        #print('transit_time_increase_outbound', 'transit_time_increase_return', transit_time_increase_distribution_outbound, transit_time_increase_distribution_return)
        #print('')

    # Calculate new transit days after the increase
    new_transit_days_outbound = current_transit_time_outbound * (1 + transit_time_increase_outbound)
    new_transit_days_return = current_transit_time_return * (1 + transit_time_increase_return)

    #print('Iteration %d' %i)
    #print(f'Freight Rate (Outbound): {freight_rate_outbound:.2f} USD/TEU')
    #print(f'Freight Rate (Return): {freight_rate_return:.2f} USD/TEU')
    #print('new_transit_days_outbound', new_transit_days_outbound)
    #print('new_transit_days_return', new_transit_days_return)

    # Total revenue calculation (outbound and return)
    total_revenue_outbound = total_full_teu_outbound * freight_rate_outbound
    total_revenue_return = total_full_teu_return * freight_rate_return
    #print('total_revenue_outbound', total_revenue_outbound)
    #print('total_revenue_return', total_revenue_return)

    # Total revenue per Day (outbound and return)
    total_revenue_per_day_outbound = total_revenue_outbound / new_transit_days_outbound
    total_revenue_per_day_return = total_revenue_return / new_transit_days_return
    #print('total_revenue_per_day_outbound', total_revenue_per_day_outbound)
    #print('total_revenue_per_day_return', total_revenue_per_day_return)

    # Utilization Rate calculation
    utilization_outbound = (total_full_teu_outbound + total_empty_teu_outbound + additional_empties_outbound) / operational_allowance_outbound
    utilization_return = (total_full_teu_return + total_empty_teu_return + additional_empties_return) / operational_allowance_return
    #print('utilization_outbound', utilization_outbound)
    #print('utilization_return', utilization_return)

    # Loss of revenue due to Repositioning (only for specific regions)
    if row_outbound['Region'] in regions_with_loss_of_revenue:
        loss_of_revenue_due_to_repositioning_outbound = freight_rate_outbound * additional_empties_outbound
    else:
        loss_of_revenue_due_to_repositioning_outbound = 0

    if row_return['Region'] in regions_with_loss_of_revenue:
        loss_of_revenue_due_to_repositioning_return = freight_rate_return * additional_empties_return
    else:
        loss_of_revenue_due_to_repositioning_return = 0

    # Calculate the total loss of revenue per iteration
    total_loss_of_revenue_due_to_repositioning_value = loss_of_revenue_due_to_repositioning_outbound + loss_of_revenue_due_to_repositioning_return

    #print('loss_of_revenue_due_to_repositioning_outbound', loss_of_revenue_due_to_repositioning_outbound)
    #print('loss_of_revenue_due_to_repositioning_return', loss_of_revenue_due_to_repositioning_return)


    # Loss of revenue per Day (outbound and return)
    if loss_of_revenue_due_to_repositioning_outbound == 0:
        loss_of_revenue_per_day_outbound = 0
    else:
        loss_of_revenue_per_day_outbound = loss_of_revenue_due_to_repositioning_outbound / new_transit_days_outbound

    if loss_of_revenue_due_to_repositioning_return == 0:
        loss_of_revenue_per_day_return = 0
    else:
        loss_of_revenue_per_day_return = loss_of_revenue_due_to_repositioning_return / new_transit_days_return
    #print('loss_of_revenue_per_day_outbound', loss_of_revenue_per_day_outbound)
    #print('loss_of_revenue_per_day_return', loss_of_revenue_per_day_return)

    # Total Revenue
    total_revenue_outbound = (total_revenue_outbound + loss_of_revenue_due_to_repositioning_outbound)
    total_revenue_return = (total_revenue_return + loss_of_revenue_due_to_repositioning_return)
    total_revenue_value = (total_revenue_outbound + total_revenue_return)
    #print('total_revenue_outbound', total_revenue_outbound)
    #print('total_revenue_return', total_revenue_return)
    #print('total_revenue_value', total_revenue_value)

    # Total Revenue per Day
```

```
        total_revenue_per_day_outbound = (total_revenue_per_day_outbound + loss_of_revenue_per_day_outbound)
        total_revenue_per_day_return = (total_revenue_per_day_return + loss_of_revenue_per_day_return)
        total_revenue_per_day_value = (total_revenue_per_day_outbound + total_revenue_per_day_return)
        #print('total_revenue_per_day_outbound', total_revenue_per_day_outbound)
        #print('total_revenue_per_day_return', total_revenue_per_day_return)
        #print('total_revenue_per_day_value', total_revenue_per_day_value)


        # Store results
        total_revenue.append(total_revenue_value)
        total_revenue_per_day.append(total_revenue_per_day_value)
        utilization_rate_outbound.append(utilization_outbound)
        utilization_rate_return.append(utilization_return)
        loss_of_revenue_per_day.append(loss_of_revenue_per_day_outbound + loss_of_revenue_per_day_return)
        total_loss_of_revenue_due_to_repositioning.append(total_loss_of_revenue_due_to_repositioning_value)

    # Return results for this region pair
    return pd.DataFrame({
        'Total Revenue': total_revenue,
        'Total Revenue per Day': total_revenue_per_day,
        'Utilization Rate Outbound': utilization_rate_outbound,
        'Utilization Rate Return': utilization_rate_return,
        'Freight Rate per TEU Outbound':freight_rate_outbound,
        'Freight Rate per TEU Return':freight_rate_return,
        'Average Transit Days Outbound':new_transit_days_outbound,
        'Average Transit Days Return':new_transit_days_return,
        'Additional Empties Outbound':additional_empties_outbound,
        'Additional Empties Return':additional_empties_return,
        'Loss of Revenue per Day': loss_of_revenue_per_day,
        'Total Loss of Revenue due to Repositioning': total_loss_of_revenue_due_to_repositioning
        })

# Function to handle the scenario logic for additional_empties based on the rules
def apply_additional_empties_scenarios(far_east_to_eu_outbound_value, scenario):
    additional_empties = {
        'EU to Africa': 0,
        'EU to Latin America': 0,
        'EU to North America': 0,
        'Africa to EU': 0,
        'Latin America to EU': 0,
        'North America to EU': 0,
        'Far East to EU': far_east_to_eu_outbound_value,  # Far East from to EU mirrors its outbound value
        'EU to Far East': far_east_to_eu_outbound_value  # EU to Far East gets the outbound value too
    }

    # Apply the scenario logic for outbound values
    if scenario == 1:
        additional_empties['EU to Africa'] = -far_east_to_eu_outbound_value
    elif scenario == 2:
        additional_empties['EU to Latin America'] = -far_east_to_eu_outbound_value
    elif scenario == 3:
        additional_empties['EU to North America'] = -far_east_to_eu_outbound_value
    elif scenario == 4:
        # This scenario distributes the negative value across the three regions
        total_split = -far_east_to_eu_outbound_value
        additional_empties['EU to Africa'] = total_split / 3
        additional_empties['EU to Latin America'] = total_split / 3
        additional_empties['EU to North America'] = total_split / 3

    return additional_empties

# Initialize dictionary to store results for all scenarios and regions
results = {scenario: {} for scenario in range(1, 5)}

# Main simulation process to handle the randomized values
for i in range(iterations):
    # Randomize the additional_empties_outbound for "Far East from to EU"
    if i_month == 1:
        additional_empties_outbound_far_east = np.random.uniform(low=73, high=1084)
    elif i_month == 2:
        additional_empties_outbound_far_east = np.random.uniform(low=465, high=1374)
    elif i_month == 3:
        additional_empties_outbound_far_east = np.random.uniform(low=352, high=1719)
    elif i_month == 4:
        additional_empties_outbound_far_east = np.random.uniform(low=364, high=892)
    elif i_month == 5:
        additional_empties_outbound_far_east = np.random.uniform(low=648, high=1462)
    elif i_month == 6:
        additional_empties_outbound_far_east = np.random.uniform(low=608, high=1398)
    elif i_month == 7:
        additional_empties_outbound_far_east = np.random.uniform(low=145, high=1054)
    elif i_month == 8:
        additional_empties_outbound_far_east = np.random.uniform(low=307, high=786)
    elif i_month == 9:
        additional_empties_outbound_far_east = np.random.uniform(low=187, high=752)
    elif i_month == 10:
        additional_empties_outbound_far_east = np.random.uniform(low=329, high=787)
    elif i_month == 11:
```

```
        additional_empties_outbound_far_east = np.random.uniform(low=185, high=744)
    elif i_month == 12:
        additional_empties_outbound_far_east = np.random.uniform(low=320, high=1232)

    # Define outbound and return trip pairs
    region_pairs = {
        'Far East from to EU': ('EU to Far East', 'Far East to EU'),
        'Africa from to EU': ('EU to Africa', 'Africa to EU'),
        'Latin America from to EU': ('EU to Latin America', 'Latin America to EU'),
        'North America from to EU': ('EU to North America', 'North America to EU')
    }

    # Process each of the four scenarios
    for scenario in range(1, 5):
        #print(f"DEBUG: Processing Scenario {scenario}, Month {i_month}")  # Debugging

        # Process each pair of regions for this scenario
        for region_pair, (outbound, return_trip) in region_pairs.items():
            #print(f"DEBUG: Processing Region {region_pair} in Scenario {scenario}, Month {i_month}")  # Debugging

            # Apply the scenario to determine the additional empties for other regions
            additional_empties = apply_additional_empties_scenarios(additional_empties_outbound_far_east, scenario)

            # Ensure the data filtering returns a non-empty DataFrame
            row_outbound = data[data['Region'] == outbound]
            row_return = data[data['Region'] == return_trip]

            #print(f"Outbound: {outbound}, Return: {return_trip}")
            #print(f"Row Outbound: {row_outbound}")
            #print(f"Row Return: {row_return}")

            if row_outbound.empty or row_return.empty:
                print(f"WARNING: Skipping {region_pair} in Scenario {scenario}, Month {i_month} due to missing data")
                continue

            # Access the first row of filtered results
            row_outbound = row_outbound.iloc[0]
            row_return = row_return.iloc[0]

            # Pass the specific additional empties value from the scenario logic
            additional_empties_outbound = additional_empties[outbound]
            additional_empties_return = additional_empties[return_trip]

            base_freight_rate_outbound = pd.to_numeric(row_outbound['Freight Rate per TEU'], errors='coerce')
            base_freight_rate_return = pd.to_numeric(row_return['Freight Rate per TEU'], errors='coerce')

            try:
                min_freight_rate_outbound = base_freight_rate_outbound * (1+data_var[data_var['Region'] == outbound]['Var Min_Freight Rate per TEU'])
                max_freight_rate_outbound = base_freight_rate_outbound * (1+data_var[data_var['Region'] == outbound]['Var Max_Freight Rate per TEU'])
                min_freight_rate_return = base_freight_rate_return * (1+data_var[data_var['Region'] == return_trip]['Var Min_Freight Rate per TEU'])
                max_freight_rate_return = base_freight_rate_return * (1+data_var[data_var['Region'] == return_trip]['Var Max_Freight Rate per TEU'])
            except IndexError:
                print(f"ERROR: Missing variable data for {outbound} or {return_trip} in Scenario {scenario}, Month {i_month}")
                continue

            # Perform the region revenue calculation
            result_df = calculate_revenue_for_region(row_outbound, row_return, additional_empties_outbound, additional_empties_return, min_freight_rate_outbound,max_freight_rate_outbound,
min_freight_rate_return, max_freight_rate_return)

            # Store the results for this month, scenario and region pair
            if i_month not in monthly_results:
                monthly_results[i_month] = {}

            # Store the results for this month, scenario, and region pair
            if not result_df.empty:

                if scenario not in monthly_results[i_month]:
                    monthly_results[i_month][scenario] = {}

                monthly_results[i_month][scenario][region_pair] = result_df.copy()

    # Store results for this month
    import copy

    # Ensure the dictionary is initialized before accessing keys
    if i_month not in monthly_results:
        monthly_results[i_month] = {}

    if scenario not in monthly_results[i_month]:
        monthly_results[i_month][scenario] = {}

    if region not in monthly_results[i_month][scenario]:
        monthly_results[i_month][scenario][region] = {}

    monthly_results[i_month][scenario][region] = copy.deepcopy(result_df)
```

```
# Adjusted Total Revenue Calculation for 'Far East from to EU'
for scenario in range(1, 5):
    if i_month in monthly_results and scenario in monthly_results[i_month]:
        if 'Far East from to EU' in monthly_results[i_month][scenario]:
            #print(f"✅ Available keys in monthly_results[{i_month}][{scenario}]: {list(monthly_results[i_month][scenario].keys())}")

            fe_df = monthly_results[i_month][scenario]['Far East from to EU']

            # Ensure columns exist before modification
            if 'Adjusted Total Revenue' not in fe_df.columns:
                fe_df['Adjusted Total Revenue'] = np.nan
                fe_df['Adjusted Total Revenue per Day'] = np.nan

            # Apply calculation based on scenario
            if scenario == 1:
                eu_to_africa = monthly_results[i_month][scenario].get('Africa from to EU', pd.DataFrame())
                fe_df['Adjusted Total Revenue'] = fe_df['Total Revenue'] + eu_to_africa.get('Total Loss of Revenue due to Repositioning', 0)
                fe_df['Adjusted Total Revenue per Day'] = fe_df['Total Revenue per Day'] + eu_to_africa.get('Loss of Revenue per Day', 0)
            elif scenario == 2:
                eu_to_latin_america = monthly_results[i_month][scenario].get('Latin America from to EU', pd.DataFrame())
                fe_df['Adjusted Total Revenue'] = fe_df['Total Revenue'] + eu_to_latin_america.get('Total Loss of Revenue due to Repositioning', 0)
                fe_df['Adjusted Total Revenue per Day'] = fe_df['Total Revenue per Day'] + eu_to_latin_america.get('Loss of Revenue per Day', 0)
            elif scenario == 3:
                eu_to_north_america = monthly_results[i_month][scenario].get('North America from to EU', pd.DataFrame())
                fe_df['Adjusted Total Revenue'] = fe_df['Total Revenue'] + eu_to_north_america.get('Total Loss of Revenue due to Repositioning', 0)
                fe_df['Adjusted Total Revenue per Day'] = fe_df['Total Revenue per Day'] + eu_to_north_america.get('Loss of Revenue per Day', 0)
            elif scenario == 4:
                eu_to_africa = monthly_results[i_month][scenario].get('Africa from to EU', pd.DataFrame())
                eu_to_latin_america = monthly_results[i_month][scenario].get('Latin America from to EU', pd.DataFrame())
                eu_to_north_america = monthly_results[i_month][scenario].get('North America from to EU', pd.DataFrame())

                fe_df['Adjusted Total Revenue'] = (
                    fe_df['Total Revenue'] +
                    eu_to_africa.get('Total Loss of Revenue due to Repositioning', 0) +
                    eu_to_latin_america.get('Total Loss of Revenue due to Repositioning', 0) +
                    eu_to_north_america.get('Total Loss of Revenue due to Repositioning', 0)
                )
                fe_df['Adjusted Total Revenue per Day'] = (
                    fe_df['Total Revenue per Day'] +
                    eu_to_africa.get('Loss of Revenue per Day', 0) +
                    eu_to_latin_america.get('Loss of Revenue per Day', 0) +
                    eu_to_north_america.get('Loss of Revenue per Day', 0)
                )

            monthly_results[i_month][scenario]['Far East from to EU'] = fe_df.copy()
        else:
            print(f"⚠️ ERROR: 'Far East from to EU' is missing from monthly_results[{i_month}][{scenario}]!")

    #print(f"\nScenario {scenario}: Adjusted Revenue Calculation for 'Far East from to EU'")
    #print(fe_df[['Total Revenue', 'Adjusted Total Revenue']].describe() if 'Adjusted Total Revenue' in fe_df.columns else "⚠️ WARNING: Adjusted Total Revenue is missing from the dataset!")


# Analyze results for each region pair and scenario
for month in sorted(monthly_results.keys()):
    if month in processed_months:
        continue  # Skip reprocessing already printed months

    print(f"Processing Month {month}")
    processed_months.add(month)  # Track processed months

    for scenario in sorted(monthly_results[month].keys()):
        print(f"Summary for Scenario {scenario}, Month {month}:")

        for region in sorted(monthly_results[month][scenario].keys()):
            result_df = monthly_results[month][scenario][region]

            print(f"Summary for {region} (Scenario {scenario}, Month {month})")

            print()

    print()


import pandas as pd

# Initialize a list to store full-year results per iteration
full_year_iterations = []

# Iterate over scenarios
for scenario in range(1, 5):
    # Process each region separately
    for region in ['Far East from to EU', 'Africa from to EU', 'Latin America from to EU', 'North America from to EU']:

        num_iterations = 0  # Default to zero

        # Find the maximum number of iterations dynamically by checking all months
        for month in range(1, 13):
```

```python
            if month in monthly_results and scenario in monthly_results[month]:
                if region in monthly_results[month][scenario]:
                    df = monthly_results[month][scenario][region]
                    if not df.empty:
                        num_iterations = max(num_iterations, len(df))  # Get the max number of iterations

        if num_iterations == 0:
            print(f"Skipping {region} in Scenario {scenario} due to missing data.")
            continue  # Skip if no valid data exists for this region-scenario

        # Process each iteration separately
        for i in range(num_iterations):
            sum_total_revenue = 0
            sum_total_revenue_per_day = 0

            # Iterate over all 12 months for the same iteration index
            for month in range(1, 13):
                if month in monthly_results and scenario in monthly_results[month]:
                    if region in monthly_results[month][scenario]:
                        df = monthly_results[month][scenario][region]

                        # Check if iteration i exists in the DataFrame
                        if i < len(df):
                            row = df.iloc[i]  # Select iteration i

                            if region == 'Far East from to EU':
                                sum_total_revenue += row.get('Adjusted Total Revenue', 0)
                                sum_total_revenue_per_day += row.get('Adjusted Total Revenue per Day', 0)
                            else:
                                sum_total_revenue += row.get('Total Revenue', 0)
                                sum_total_revenue_per_day += row.get('Total Revenue per Day', 0)

            # Store each iteration as a separate row
            full_year_iterations.append({
                'Iteration': i + 1,
                'Scenario': scenario,
                'Region': region,
                'Full Year Total Revenue': sum_total_revenue,
                'Full Year Revenue per Day': sum_total_revenue_per_day
            })

# Convert list to DataFrame
df_full_year_iterations = pd.DataFrame(full_year_iterations)

# Display the full-year aggregated iteration-wise data
#print("\nFull Year Aggregated Iteration Data:")
#print(df_full_year_iterations)

# Apply describe() for each region and scenario separately
print("\nSummary Statistics for Each Region and Scenario:\n")

# Group the DataFrame by scenario and region and display describe() separately
for scenario in range(1, 5):
    for region in ['Far East from to EU', 'Africa from to EU', 'Latin America from to EU', 'North America from to EU']:
        df_subset = df_full_year_iterations[
            (df_full_year_iterations['Scenario'] == scenario) &
            (df_full_year_iterations['Region'] == region)
        ]

        if not df_subset.empty:
            print(f"Scenario {scenario} - {region}:\n")
            print(df_subset[['Full Year Total Revenue', 'Full Year Revenue per Day']].describe())
            print("\n" + "="*80 + "\n")  # Separator for readability



import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns

# Define the scenarios and regions
regions = ['Far East from to EU', 'Africa from to EU', 'Latin America from to EU', 'North America from to EU']
scenarios = [1, 2, 3, 4]

# Create a new DataFrame for visualization
df_all_scenarios = pd.DataFrame()

# Loop through each scenario and region and prepare the data
for scenario in scenarios:
    for region in regions:
        temp_df = df_full_year_iterations[
            (df_full_year_iterations['Scenario'] == scenario) &
            (df_full_year_iterations['Region'] == region)
        ].copy()

        if not temp_df.empty:
            temp_df['Region'] = region
            temp_df['Scenario'] = f'Scenario {scenario}'
```

```python
        df_all_scenarios = pd.concat([df_all_scenarios, temp_df], ignore_index=True)

# Ensure there is data before plotting
if not df_all_scenarios.empty:
    # Create a FacetGrid for visualization
    g = sns.FacetGrid(df_all_scenarios, col="Region", row="Scenario", height=4, aspect=1.5, sharex=True)
    g.map(sns.histplot, "Full Year Total Revenue", kde=False, color='skyblue', edgecolor='black')  # Histogram styling

    # Add global axis labels
    g.set_axis_labels("Full Year Total Revenue", "Frequency")
    g.set_ylabels("Frequency", fontsize=16, color="black")
    for ax in g.axes.flat:
        ax.set_xlabel("Total Revenue", fontsize=18, color="black")

    # Ensure all x-axis tick labels are shown for each subplot
    for ax in g.axes.flat:
        ax.tick_params(axis='x', which='both', labelbottom=True)  # Enable x-axis labels for all subplots

    # Customize tick labels and rotation
    for ax in g.axes.flat:
        ax.set_xlabel("Full Year Total Revenue", fontsize=14, color="black")
        ax.tick_params(axis='x', labelsize=12, labelcolor='black', rotation=45)
        ax.tick_params(axis='y', labelsize=12, labelcolor='black')

        # Bold x and y tick labels
        for tick in ax.get_xticklabels():
            tick.set_fontweight("bold")
        for tick in ax.get_yticklabels():
            tick.set_fontweight("bold")

    # Simplify subplot titles
    for ax in g.axes.flat:
        ax.set_title(ax.get_title().replace("Scenario = ", "").replace("Region = ", ""), fontsize=14, color="black")

    # Add overall title
    g.fig.suptitle("Distribution of Full Year Total Revenue Across Regions and Scenarios", y=1.05, fontsize=18, color="black")

    # Adjust spacing between subplots
    plt.subplots_adjust(hspace=0.5, wspace=0.1)

    # Adjust figure size for better clarity
    g.fig.set_size_inches(16, 12)

    # Show the plot
    plt.show()
else:
    print("No data available for visualization.")
```

Appendix J

Statistical Summary from Alternative 1

Summary for Far East from to EU

	Total Revenue	Total Revenue per Day	Utilization Rate Outbound \
count	5.000000e+02	5.000000e+02	5.000000e+02
mean	5.411602e+09	9.584120e+07	7.100002e+05
std	7.283634e+08	1.399072e+07	4.661276e-10
min	4.146907e+09	6.821955e+07	7.100002e+05
25%	4.751869e+09	8.488557e+07	7.100002e+05
50%	5.404897e+09	9.472907e+07	7.100002e+05
75%	6.087447e+09	1.060926e+08	7.100002e+05
max	6.660592e+09	1.288217e+08	7.100002e+05

	Utilization Rate Return	Freight Rate per TEU Outbound \
count	5.000000e+02	500.000000
mean	2.260000e+06	236.616516
std	6.991915e-09	32.860830
min	2.260000e+06	182.573519
25%	2.260000e+06	207.899831
50%	2.260000e+06	233.364344
75%	2.260000e+06	265.708485
max	2.260000e+06	295.761327

	Freight Rate per TEU Return	Average Transit Days Outbound \
count	500.000000	500.000000
mean	2320.178666	63.546810
std	321.487005	3.935667
min	1761.678055	56.708096
25%	2026.260676	60.075380
50%	2314.418947	63.786562
75%	2612.900312	66.825670
max	2857.851448	70.188659

	Average Transit Days Return
count	500.000000
mean	56.453932
std	3.373354
min	50.419226
25%	53.719141
50%	56.533559
75%	59.274998
max	62.391854

Summary for Africa from to EU

	Total Revenue	Total Revenue per Day	Utilization Rate Outbound \
count	5.000000e+02	5.000000e+02	5.000000e+02
mean	3.336168e+08	8.990293e+06	1.050001e+05
std	3.403482e+07	1.017338e+06	4.078617e-10
min	2.572491e+08	6.556915e+06	1.050001e+05
25%	3.077510e+08	8.191538e+06	1.050001e+05
50%	3.334272e+08	8.975333e+06	1.050001e+05
75%	3.590356e+08	9.732272e+06	1.050001e+05
max	4.090849e+08	1.199870e+07	1.050001e+05

	Utilization Rate Return	Freight Rate per TEU Outbound \
count	5.000000e+02	500.000000
mean	1.020001e+05	2036.215987
std	5.826596e-11	283.939098
min	1.020001e+05	1556.307093
25%	1.020001e+05	1791.566198
50%	1.020001e+05	2033.638027
75%	1.020001e+05	2283.161086
max	1.020001e+05	2525.897035

	Freight Rate per TEU Return	Average Transit Days Outbound \
count	500.000000	500.000000
mean	1174.647868	36.336411
std	156.876188	2.278624
min	889.656760	32.596695
25%	1039.581068	34.334303
50%	1179.773153	36.300480
75%	1315.633135	38.263749
max	1441.202103	40.280468

	Average Transit Days Return
count	500.000000
mean	38.981068
std	2.373513
min	34.654202
25%	36.931123
50%	39.112751
75%	41.082180
max	42.896134

Summary for Latin America from to EU

	Total Revenue	Total Revenue per Day	Utilization Rate Outbound
count	5.000000e+02	5.000000e+02	5.000000e+02
mean	6.179189e+08	2.209986e+07	2.500000e+05
std	6.207572e+07	2.521176e+06	2.359771e-09
min	4.764139e+08	1.627208e+07	2.500000e+05
25%	5.711158e+08	2.032246e+07	2.500000e+05
50%	6.170680e+08	2.193519e+07	2.500000e+05
75%	6.638689e+08	2.394589e+07	2.500000e+05
max	7.573839e+08	2.793867e+07	2.500000e+05

	Utilization Rate Return	Freight Rate per TEU Outbound
count	5.000000e+02	500.000000
mean	2.500000e+05	1081.890823
std	2.709367e-09	147.761939
min	2.500000e+05	827.443489
25%	2.500000e+05	962.912738
50%	2.500000e+05	1070.405152
75%	2.500000e+05	1205.853434
max	2.500000e+05	1339.342799

	Freight Rate per TEU Return	Average Transit Days Outbound
count	500.000000	500.000000
mean	1389.784916	31.609264
std	194.089961	1.901432
min	1054.873970	28.355336
25%	1221.198682	29.917634
50%	1397.482170	31.635753
75%	1554.102670	33.155392
max	1711.569257	35.084506

	Average Transit Days Return
count	500.000000
mean	25.826680
std	1.610487
min	23.117863
25%	24.370067
50%	25.823985
75%	27.296812
max	28.587039

Summary for North America from to EU

	Total Revenue	Total Revenue per Day	Utilization Rate Outbound
count	5.000000e+02	5.000000e+02	5.000000e+02
mean	1.400168e+09	7.073229e+07	6.700000e+05
std	1.701273e+08	9.351345e+06	5.710064e-09
min	1.083109e+09	5.032945e+07	6.700000e+05
25%	1.254508e+09	6.333749e+07	6.700000e+05
50%	1.396716e+09	7.083768e+07	6.700000e+05
75%	1.551292e+09	7.747388e+07	6.700000e+05
max	1.734943e+09	9.370157e+07	6.700000e+05

	Utilization Rate Return	Freight Rate per TEU Outbound
count	5.000000e+02	500.000000
mean	2.300000e+05	1803.051772
std	1.660580e-09	249.825116
min	2.300000e+05	1378.164423
25%	2.300000e+05	1586.225944
50%	2.300000e+05	1799.333170
75%	2.300000e+05	2024.866936
max	2.300000e+05	2237.493571

	Freight Rate per TEU Return	Average Transit Days Outbound
count	500.000000	500.000000
mean	835.317576	20.053769
std	109.729064	1.254319
min	639.319349	17.850956
25%	743.672144	18.953227
50%	831.845976	19.986546
75%	918.578299	21.160348
max	1038.395232	22.096716

	Average Transit Days Return
count	500.000000
mean	18.796349
std	1.137001
min	16.817969
25%	17.843336
50%	18.743174
75%	19.719909
max	20.792493

Appendix K

Statistical Summary from Alternative 1 (No Seasonality)

Summary for Far East from to EU (Scenario 1)

	Total Revenue	Total Revenue per Day	Utilization Rate Outbound
count	2.500000e+05	2.500000e+05	250000.000000
mean	5.445549e+09	9.658436e+07	0.978864
std	7.262469e+08	1.425418e+07	0.011956
min	4.120796e+09	6.609486e+07	0.958966
25%	4.816802e+09	8.508478e+07	0.968291
50%	5.447865e+09	9.625658e+07	0.979056
75%	6.072389e+09	1.073614e+08	0.988888
max	6.788435e+09	1.333686e+08	0.999964

	Utilization Rate Return	Freight Rate per TEU Outbound
count	250000.000000	250000.000000
mean	0.955861	237.918993
std	0.004403	33.181925
min	0.948534	182.554915
25%	0.951968	208.931586
50%	0.955932	237.112414
75%	0.959553	266.058795
max	0.963632	296.329157

	Freight Rate per TEU Return	Average Transit Days Outbound
count	250000.000000	250000.000000
mean	2316.647376	63.854416
std	316.891702	3.908157
min	1765.411185	56.727801
25%	2055.084304	60.537374
50%	2298.248736	63.923265
75%	2590.508401	67.363559
max	2862.583236	70.196570

	Average Transit Days Return	Additional Empties Outbound
count	250000.000000	250000.000000
mean	56.759481	21241.559422
std	3.473918	10554.241618
min	50.424712	3677.631066
25%	53.810999	11909.086498
50%	56.820680	21411.320145
75%	59.878719	30089.758072
max	62.396951	39867.283991

	Additional Empties Return	Loss of Revenue per Day
count	250000.000000	2.500000e+05
mean	21241.559422	8.741292e+05
std	10554.241618	4.585068e+05
min	3677.631066	1.048059e+05
25%	11909.086498	4.767201e+05
50%	21411.320145	8.545540e+05
75%	30089.758072	1.223234e+06
max	39867.283991	2.241446e+06

	Total Loss of Revenue due to Repositioning	Adjusted Total Revenue
count	2.500000e+05	2.500000e+05
mean	4.911718e+07	5.402199e+09
std	2.554179e+07	7.259020e+08
min	6.482881e+06	4.092557e+09
25%	2.683806e+07	4.773839e+09
50%	4.819138e+07	5.404070e+09
75%	6.886487e+07	6.029379e+09
max	1.140696e+08	6.718090e+09

	Adjusted Total Revenue per Day
count	2.500000e+05
mean	9.538967e+07
std	1.425053e+07
min	6.456127e+07
25%	8.389862e+07
50%	9.506960e+07
75%	1.061550e+08
max	1.316541e+08

Summary for Africa from to EU (Scenario 1)

	Total Revenue	Total Revenue per Day	Utilization Rate Outbound
count	2.500000e+05	2.500000e+05	250000.000000
mean	2.897518e+08	7.786615e+06	0.702925
std	3.597123e+07	1.092063e+06	0.079042
min	1.936102e+08	4.719635e+06	0.563434
25%	2.635518e+08	6.994578e+06	0.636660
50%	2.879983e+08	7.723270e+06	0.701653
75%	3.144692e+08	8.512204e+06	0.772817
max	4.010742e+08	1.199444e+07	0.834463

	Utilization Rate Return	Freight Rate per TEU Outbound
count	2.500000e+05	250000.000000
mean	6.988014e-01	2063.994075
std	5.390144e-13	280.535583
min	6.988014e-01	1556.150868
25%	6.988014e-01	1832.976691
50%	6.988014e-01	2069.513598
75%	6.988014e-01	2308.383735
max	6.988014e-01	2525.536532

	Freight Rate per TEU Return	Average Transit Days Outbound
count	250000.000000	250000.000000
mean	1157.953902	36.416650
std	158.455554	2.187839
min	887.367596	32.581982
25%	1014.945766	34.543403
50%	1162.077799	36.358290
75%	1293.806267	38.329562
max	1435.898502	40.288098

	Average Transit Days Return	Additional Empties Outbound
count	250000.000000	250000.000000
mean	38.766112	-21241.559422
std	2.328990	10554.241618
min	34.684046	-39867.283991
25%	36.772010	-30089.758072
50%	38.703986	-21411.320145
75%	40.802437	-11909.086498
max	42.887330	-3677.631066

	Additional Empties Return	Loss of Revenue per Day
count	250000.0	2.500000e+05
mean	0.0	-1.194692e+06
std	0.0	6.270096e+05
min	0.0	-3.062024e+06
25%	0.0	-1.672295e+06
50%	0.0	-1.167426e+06
75%	0.0	-6.510175e+05
max	0.0	-1.431101e+05

	Total Loss of Revenue due to Repositioning
count	2.500000e+05
mean	-4.334984e+07
std	2.254758e+07
min	-1.006561e+08
25%	-6.081699e+07
50%	-4.255625e+07
75%	-2.366682e+07
max	-5.722684e+06

```
Summary for Latin America from to EU (Scenario 1)
       Total Revenue  Total Revenue per Day  Utilization Rate Outbound  \
count   2.500000e+05           2.500000e+05               2.500000e+05
mean    6.172582e+08           2.201410e+07               8.046006e-01
std     6.048618e+07           2.583477e+06               4.076969e-12
min     4.705514e+08           1.526673e+07               8.046006e-01
25%     5.735322e+08           2.013084e+07               8.046006e-01
50%     6.171879e+08           2.192829e+07               8.046006e-01
75%     6.609032e+08           2.379956e+07               8.046006e-01
max     7.640750e+08           3.028638e+07               8.046006e-01

       Utilization Rate Return  Freight Rate per TEU Outbound  \
count             2.500000e+05                  250000.000000
mean              7.814990e-01                    1094.901405
std               2.173488e-12                     144.930840
min               7.814990e-01                     829.441572
25%               7.814990e-01                     969.362881
50%               7.814990e-01                    1101.576363
75%               7.814990e-01                    1219.825046
max               7.814990e-01                    1344.173451

       Freight Rate per TEU Return  Average Transit Days Outbound  \
count                250000.000000                  250000.000000
mean                   1372.952395                      31.694216
std                     195.799006                       1.958461
min                    1054.778974                      28.350650
25%                    1201.068591                      30.007060
50%                    1360.365337                      31.579190
75%                    1546.271513                      33.350120
max                    1713.317283                      35.094105

       Average Transit Days Return  Additional Empties Outbound  \
count                250000.000000                     250000.0
mean                     25.824917                          0.0
std                       1.595783                          0.0
min                      23.100529                          0.0
25%                      24.450197                          0.0
50%                      25.731192                          0.0
75%                      27.174172                          0.0
max                      28.595197                          0.0

       Additional Empties Return  Loss of Revenue per Day  \
count                   250000.0                 250000.0
mean                         0.0                      0.0
std                          0.0                      0.0
min                          0.0                      0.0
25%                          0.0                      0.0
50%                          0.0                      0.0
75%                          0.0                      0.0
max                          0.0                      0.0

       Total Loss of Revenue due to Repositioning
count                                    250000.0
mean                                          0.0
std                                           0.0
min                                           0.0
25%                                           0.0
50%                                           0.0
75%                                           0.0
max                                           0.0
```

Summary for North America from to EU (Scenario 1)

	Total Revenue	Total Revenue per Day	Utilization Rate Outbound \
count	2.500000e+05	2.500000e+05	2.500000e+05
mean	1.405058e+09	7.121757e+07	8.978997e-01
std	1.686447e+08	9.576541e+06	3.100193e-12
min	1.071201e+09	4.903795e+07	8.978997e-01
25%	1.260938e+09	6.371570e+07	8.978997e-01
50%	1.405129e+09	7.095655e+07	8.978997e-01
75%	1.549431e+09	7.826528e+07	8.978997e-01
max	1.738169e+09	9.796081e+07	8.978997e-01

	Utilization Rate Return	Freight Rate per TEU Outbound \
count	2.500000e+05	250000.000000
mean	8.217986e-01	1815.437603
std	2.937323e-12	250.638282
min	8.217986e-01	1379.029942
25%	8.217986e-01	1591.291699
50%	8.217986e-01	1832.557368
75%	8.217986e-01	2027.611390
max	8.217986e-01	2234.840115

	Freight Rate per TEU Return	Average Transit Days Outbound \
count	250000.000000	250000.000000
mean	850.548161	19.989954
std	112.485941	1.221655
min	640.455457	17.850775
25%	756.608750	18.921106
50%	853.681471	20.069384
75%	945.604220	20.993731
max	1037.631020	22.097908

	Average Transit Days Return	Additional Empties Outbound \
count	250000.000000	250000.0
mean	18.814074	0.0
std	1.149793	0.0
min	16.800729	0.0
25%	17.808099	0.0
50%	18.888832	0.0
75%	19.758806	0.0
max	20.798031	0.0

	Additional Empties Return	Loss of Revenue per Day \
count	250000.0	250000.0
mean	0.0	0.0
std	0.0	0.0
min	0.0	0.0
25%	0.0	0.0
50%	0.0	0.0
75%	0.0	0.0
max	0.0	0.0

	Total Loss of Revenue due to Repositioning
count	250000.0
mean	0.0
std	0.0
min	0.0
25%	0.0
50%	0.0
75%	0.0
max	0.0

```
Summary for Far East from to EU (Scenario 2)
       Total Revenue  Total Revenue per Day  Utilization Rate Outbound  \
count   2.500000e+05           2.500000e+05              250000.000000
mean    5.446189e+09           9.657942e+07                   0.978864
std     7.258376e+08           1.424744e+07                   0.011956
min     4.123547e+09           6.633266e+07                   0.958966
25%     4.819590e+09           8.509717e+07                   0.968291
50%     5.445890e+09           9.621585e+07                   0.979056
75%     6.072459e+09           1.073184e+08                   0.988888
max     6.784975e+09           1.334804e+08                   0.999964

       Utilization Rate Return  Freight Rate per TEU Outbound  \
count            250000.000000                  250000.000000
mean                  0.955861                     236.680956
std                   0.004403                      32.689554
min                   0.948534                     182.429722
25%                   0.951968                     208.381993
50%                   0.955932                     235.406514
75%                   0.959553                     264.076630
max                   0.963632                     296.357007

       Freight Rate per TEU Return  Average Transit Days Outbound  \
count                250000.000000                  250000.000000
mean                   2322.894119                      63.540491
std                     309.391705                       3.857612
min                    1763.514214                      56.704150
25%                    2056.562009                      60.313193
50%                    2340.618129                      63.331522
75%                    2579.294229                      66.841311
max                    2858.376234                      70.090358

       Average Transit Days Return  Additional Empties Outbound  \
count                250000.000000                250000.000000
mean                     56.480436                 21241.559422
std                       3.428989                 10554.241618
min                      50.403689                  3677.631066
25%                      53.611727                 11909.086498
50%                      56.294686                 21411.320145
75%                      59.414499                 30089.758072
max                      62.302541                 39867.283991

       Additional Empties Return  Loss of Revenue per Day  \
count              250000.000000             2.500000e+05
mean                21241.559422             8.743248e+05
std                 10554.241618             4.588219e+05
min                  3677.631066             1.047157e+05
25%                 11909.086498             4.771148e+05
50%                 21411.320145             8.537176e+05
75%                 30089.758072             1.223386e+06
max                 39867.283991             2.249522e+06

       Total Loss of Revenue due to Repositioning  Adjusted Total Revenue  \
count                                2.500000e+05            2.500000e+05
mean                                 4.913071e+07            5.423128e+09
std                                  2.554627e+07            7.255513e+08
min                                  6.489017e+06            4.116250e+09
25%                                  2.684262e+07            4.796769e+09
50%                                  4.819241e+07            5.422835e+09
75%                                  6.892951e+07            6.049433e+09
max                                  1.140672e+08            6.749494e+09

       Adjusted Total Revenue per Day
count                    2.500000e+05
mean                     9.584967e+07
std                      1.424146e+07
min                      6.544448e+07
25%                      8.435920e+07
50%                      9.548158e+07
75%                      1.065950e+08
max                      1.324480e+08
```

```
Summary for Africa from to EU (Scenario 2)
       Total Revenue  Total Revenue per Day  Utilization Rate Outbound  \
count   2.500000e+05           2.500000e+05               2.500000e+05
mean    3.329086e+08           8.975470e+06               8.620054e-01
std     3.364202e+07           1.069185e+06               3.320684e-12
min     2.539008e+08           6.205941e+06               8.620054e-01
25%     3.072993e+08           8.184042e+06               8.620054e-01
50%     3.328410e+08           8.939490e+06               8.620054e-01
75%     3.584620e+08           9.724702e+06               8.620054e-01
max     4.120241e+08           1.234699e+07               8.620054e-01

       Utilization Rate Return  Freight Rate per TEU Outbound  \
count             2.500000e+05                  250000.000000
mean              6.988014e-01                    2022.326406
std               5.390144e-13                     279.293210
min               6.988014e-01                    1554.937651
25%               6.988014e-01                    1779.759141
50%               6.988014e-01                    2015.307748
75%               6.988014e-01                    2258.074830
max               6.988014e-01                    2524.622090

       Freight Rate per TEU Return  Average Transit Days Outbound  \
count                250000.000000                  250000.000000
mean                   1170.880096                      36.443030
std                     159.274875                       2.244863
min                     887.408087                      32.553262
25%                    1042.630471                      34.468030
50%                    1165.414469                      36.571960
75%                    1312.067665                      38.362677
max                    1440.383453                      40.291693

       Average Transit Days Return  Additional Empties Outbound  \
count                250000.000000                     250000.0
mean                     38.794193                          0.0
std                       2.389693                          0.0
min                      34.653472                          0.0
25%                      36.691773                          0.0
50%                      38.931442                          0.0
75%                      40.837688                          0.0
max                      42.891157                          0.0

       Additional Empties Return  Loss of Revenue per Day  \
count                   250000.0                 250000.0
mean                         0.0                      0.0
std                          0.0                      0.0
min                          0.0                      0.0
25%                          0.0                      0.0
50%                          0.0                      0.0
75%                          0.0                      0.0
max                          0.0                      0.0

       Total Loss of Revenue due to Repositioning
count                                    250000.0
mean                                          0.0
std                                           0.0
min                                           0.0
25%                                           0.0
50%                                           0.0
75%                                           0.0
max                                           0.0
```

Summary for Latin America from to EU (Scenario 2)

	Total Revenue	Total Revenue per Day	Utilization Rate Outbound \
count	2.500000e+05	2.500000e+05	250000.000000
mean	5.944419e+08	2.129907e+07	0.738642
std	5.960204e+07	2.544287e+06	0.032773
min	4.392644e+08	1.438824e+07	0.680806
25%	5.506738e+08	1.943156e+07	0.711167
50%	5.942492e+08	2.122022e+07	0.738115
75%	6.377027e+08	2.307062e+07	0.767621
max	7.578417e+08	2.980480e+07	0.793181

	Utilization Rate Return	Freight Rate per TEU Outbound \
count	2.500000e+05	250000.000000
mean	7.814990e-01	1086.645086
std	2.173488e-12	147.459941
min	7.814990e-01	828.125768
25%	7.814990e-01	961.642452
50%	7.814990e-01	1084.560668
75%	7.814990e-01	1209.142071
max	7.814990e-01	1342.689127

	Freight Rate per TEU Return	Average Transit Days Outbound \
count	250000.000000	250000.000000
mean	1378.835268	31.599393
std	190.081683	1.973713
min	1055.340280	28.356038
25%	1218.526069	29.843266
50%	1368.403862	31.646165
75%	1538.544767	33.215871
max	1712.603665	35.086872

	Average Transit Days Return	Additional Empties Outbound \
count	250000.000000	250000.000000
mean	25.747654	-21241.559422
std	1.608211	10554.241618
min	23.104920	-39867.283991
25%	24.316735	-30089.758072
50%	25.785764	-21411.320145
75%	27.064784	-11909.086498
max	28.589303	-3677.631066

	Additional Empties Return	Loss of Revenue per Day \
count	250000.0	2.500000e+05
mean	0.0	-7.297518e+05
std	0.0	3.829334e+05
min	0.0	-1.879488e+06
25%	0.0	-1.021826e+06
50%	0.0	-7.123670e+05
75%	0.0	-3.980157e+05
max	0.0	-8.690025e+04

	Total Loss of Revenue due to Repositioning
count	2.500000e+05
mean	-2.306095e+07
std	1.199112e+07
min	-5.352293e+07
25%	-3.236144e+07
50%	-2.260778e+07
75%	-1.259904e+07
max	-3.044483e+06

Summary for North America from to EU (Scenario 2)

	Total Revenue	Total Revenue per Day	Utilization Rate Outbound \
count	2.500000e+05	2.500000e+05	2.500000e+05
mean	1.404105e+09	7.115916e+07	8.978997e-01
std	1.688274e+08	9.589189e+06	3.100193e-12
min	1.070277e+09	4.929614e+07	8.978997e-01
25%	1.259554e+09	6.366249e+07	8.978997e-01
50%	1.404211e+09	7.085370e+07	8.978997e-01
75%	1.548258e+09	7.821311e+07	8.978997e-01
max	1.738354e+09	9.781122e+07	8.978997e-01

	Utilization Rate Return	Freight Rate per TEU Outbound \
count	2.500000e+05	250000.000000
mean	8.217986e-01	1816.826516
std	2.937323e-12	252.636798
min	8.217986e-01	1377.617679
25%	8.217986e-01	1589.280787
50%	8.217986e-01	1824.909326
75%	8.217986e-01	2040.103764
max	8.217986e-01	2237.719679

	Freight Rate per TEU Return	Average Transit Days Outbound \
count	250000.000000	250000.000000
mean	842.780715	19.998413
std	117.006915	1.248478
min	640.067598	17.855731
25%	737.238755	18.923774
50%	846.387465	20.026771
75%	948.972744	21.132012
max	1037.883987	22.093511

	Average Transit Days Return	Additional Empties Outbound \
count	250000.000000	250000.0
mean	18.822036	0.0
std	1.175038	0.0
min	16.805394	0.0
25%	17.810611	0.0
50%	18.848726	0.0
75%	19.888952	0.0
max	20.793893	0.0

	Additional Empties Return	Loss of Revenue per Day \
count	250000.0	250000.0
mean	0.0	0.0
std	0.0	0.0
min	0.0	0.0
25%	0.0	0.0
50%	0.0	0.0
75%	0.0	0.0
max	0.0	0.0

	Total Loss of Revenue due to Repositioning
count	250000.0
mean	0.0
std	0.0
min	0.0
25%	0.0
50%	0.0
75%	0.0
max	0.0

Summary for Scenario 3:

Summary for Far East from to EU (Scenario 3)

	Total Revenue	Total Revenue per Day	Utilization Rate Outbound \
count	2.500000e+05	2.500000e+05	250000.000000
mean	5.443333e+09	9.655954e+07	0.978864
std	7.248607e+08	1.423556e+07	0.011956
min	4.124013e+09	6.608929e+07	0.958966
25%	4.816500e+09	8.510433e+07	0.968291
50%	5.442529e+09	9.616181e+07	0.979056
75%	6.069565e+09	1.073518e+08	0.988888
max	6.789356e+09	1.336752e+08	0.999964

	Utilization Rate Return	Freight Rate per TEU Outbound \
count	250000.000000	250000.000000
mean	0.955861	240.496097
std	0.004403	33.948108
min	0.948534	182.431027
25%	0.951968	209.141772
50%	0.955932	240.805543
75%	0.959553	271.379668
max	0.963632	296.285144

	Freight Rate per TEU Return	Average Transit Days Outbound \
count	250000.000000	250000.000000
mean	2314.844599	63.363905
std	323.553957	3.833044
min	1765.490266	56.733597
25%	2030.550508	60.142330
50%	2312.161772	63.564757
75%	2617.097328	66.596792
max	2858.044962	70.137323

	Average Transit Days Return	Additional Empties Outbound \
count	250000.000000	250000.000000
mean	56.323471	21241.559422
std	3.407150	10554.241618
min	50.429864	3677.631066
25%	53.459849	11909.086498
50%	56.502006	21411.320145
75%	59.197148	30089.758072
max	62.344287	39867.283991

	Additional Empties Return	Loss of Revenue per Day \
count	250000.000000	2.500000e+05
mean	21241.559422	8.741378e+05
std	10554.241618	4.588784e+05
min	3677.631066	1.054177e+05
25%	11909.086498	4.769075e+05
50%	21411.320145	8.529994e+05
75%	30089.758072	1.224254e+06
max	39867.283991	2.246900e+06

	Total Loss of Revenue due to Repositioning	Adjusted Total Revenue \
count	2.500000e+05	2.500000e+05
mean	4.910514e+07	5.404910e+09
std	2.554724e+07	7.244865e+08
min	6.499587e+06	4.101476e+09
25%	2.681599e+07	4.778192e+09
50%	4.817601e+07	5.404615e+09
75%	6.890100e+07	6.031132e+09
max	1.140941e+08	6.733612e+09

	Adjusted Total Revenue per Day
count	2.500000e+05
mean	9.462847e+07
std	1.424150e+07
min	6.306887e+07
25%	8.319227e+07
50%	9.425973e+07
75%	1.054289e+08
max	1.309942e+08

Summary for Africa from to EU (Scenario 3)

	Total Revenue	Total Revenue per Day	Utilization Rate Outbound \
count	2.500000e+05	2.500000e+05	2.500000e+05
mean	3.330363e+08	8.980171e+06	8.620054e-01
std	3.365663e+07	1.070192e+06	3.320684e-12
min	2.538433e+08	6.183684e+06	8.620054e-01
25%	3.075370e+08	8.188515e+06	8.620054e-01
50%	3.331107e+08	8.948318e+06	8.620054e-01
75%	3.585784e+08	9.728351e+06	8.620054e-01
max	4.121788e+08	1.229515e+07	8.620054e-01

	Utilization Rate Return	Freight Rate per TEU Outbound \
count	2.500000e+05	250000.000000
mean	6.988014e-01	2033.669410
std	5.390144e-13	283.153485
min	6.988014e-01	1555.323615
25%	6.988014e-01	1800.439305
50%	6.988014e-01	2031.681514
75%	6.988014e-01	2289.045511
max	6.988014e-01	2524.791502

	Freight Rate per TEU Return	Average Transit Days Outbound \
count	250000.000000	250000.000000
mean	1173.792976	36.334861
std	166.277826	2.305633
min	889.329260	32.568832
25%	1032.032438	34.310299
50%	1183.770151	36.265439
75%	1318.842689	38.479045
max	1441.191435	40.298790

	Average Transit Days Return	Additional Empties Outbound \
count	250000.000000	250000.0
mean	38.679045	0.0
std	2.454384	0.0
min	34.670047	0.0
25%	36.523867	0.0
50%	38.605145	0.0
75%	40.961564	0.0
max	42.898712	0.0

	Additional Empties Return	Loss of Revenue per Day \
count	250000.0	250000.0
mean	0.0	0.0
std	0.0	0.0
min	0.0	0.0
25%	0.0	0.0
50%	0.0	0.0
75%	0.0	0.0
max	0.0	0.0

	Total Loss of Revenue due to Repositioning
count	250000.0
mean	0.0
std	0.0
min	0.0
25%	0.0
50%	0.0
75%	0.0
max	0.0

Summary for Latin America from to EU (Scenario 3)

	Total Revenue	Total Revenue per Day	Utilization Rate Outbound \
count	2.500000e+05	2.500000e+05	2.500000e+05
mean	6.174375e+08	2.202033e+07	8.046006e-01
std	6.040943e+07	2.585970e+06	4.076969e-12
min	4.713851e+08	1.520599e+07	8.046006e-01
25%	5.736082e+08	2.013217e+07	8.046006e-01
50%	6.175590e+08	2.193389e+07	8.046006e-01
75%	6.612383e+08	2.381247e+07	8.046006e-01
max	7.641776e+08	3.028317e+07	8.046006e-01

	Utilization Rate Return	Freight Rate per TEU Outbound \
count	2.500000e+05	250000.000000
mean	7.814990e-01	1082.166002
std	2.173488e-12	150.336760
min	7.814990e-01	827.911352
25%	7.814990e-01	952.268528
50%	7.814990e-01	1076.531577
75%	7.814990e-01	1207.307646
max	7.814990e-01	1344.168689

	Freight Rate per TEU Return	Average Transit Days Outbound \
count	250000.000000	250000.000000
mean	1389.117501	31.739080
std	199.286675	1.958575
min	1054.574444	28.355034
25%	1217.501205	30.085511
50%	1382.899581	31.720080
75%	1568.474555	33.412884
max	1713.363815	35.079955

	Average Transit Days Return	Additional Empties Outbound \
count	250000.000000	250000.0
mean	25.861472	0.0
std	1.595876	0.0
min	23.104102	0.0
25%	24.514120	0.0
50%	25.845991	0.0
75%	27.225313	0.0
max	28.583667	0.0

	Additional Empties Return	Loss of Revenue per Day \
count	250000.0	250000.0
mean	0.0	0.0
std	0.0	0.0
min	0.0	0.0
25%	0.0	0.0
50%	0.0	0.0
75%	0.0	0.0
max	0.0	0.0

	Total Loss of Revenue due to Repositioning
count	250000.0
mean	0.0
std	0.0
min	0.0
25%	0.0
50%	0.0
75%	0.0
max	0.0

Summary for North America from to EU (Scenario 3)

	Total Revenue	Total Revenue per Day	Utilization Rate Outbound
count	2.500000e+05	2.500000e+05	250000.000000
mean	1.366342e+09	6.927348e+07	0.869853
std	1.641584e+08	9.324591e+06	0.013936
min	1.017566e+09	4.712280e+07	0.845259
25%	1.226863e+09	6.197097e+07	0.858169
50%	1.366140e+09	6.899675e+07	0.869628
75%	1.505263e+09	7.610398e+07	0.882175
max	1.725984e+09	9.698257e+07	0.893044

	Utilization Rate Return	Freight Rate per TEU Outbound
count	2.500000e+05	250000.000000
mean	8.217986e-01	1829.890444
std	2.937323e-12	241.266463
min	8.217986e-01	1377.678697
25%	8.217986e-01	1625.357854
50%	8.217986e-01	1824.842309
75%	8.217986e-01	2036.577766
max	8.217986e-01	2236.179000

	Freight Rate per TEU Return	Average Transit Days Outbound
count	250000.000000	250000.000000
mean	845.992824	19.934694
std	114.784957	1.238421
min	639.492295	17.855514
25%	756.721814	18.873776
50%	841.484770	19.886148
75%	944.133384	20.992282
max	1038.383809	22.090902

	Average Transit Days Return	Additional Empties Outbound
count	250000.000000	250000.000000
mean	18.762065	-21241.559422
std	1.165573	10554.241618
min	16.805189	-39867.283991
25%	17.763554	-30089.758072
50%	18.716374	-21411.320145
75%	19.757442	-11909.086498
max	20.791438	-3677.631066

	Additional Empties Return	Loss of Revenue per Day
count	250000.0	2.500000e+05
mean	0.0	-1.931064e+06
std	0.0	1.012991e+06
min	0.0	-4.958989e+06
25%	0.0	-2.705142e+06
50%	0.0	-1.887696e+06
75%	0.0	-1.052299e+06
max	0.0	-2.326896e+05

	Total Loss of Revenue due to Repositioning
count	2.500000e+05
mean	-3.842314e+07
std	1.997759e+07
min	-8.921815e+07
25%	-5.394012e+07
50%	-3.771905e+07
75%	-2.099734e+07
max	-5.084271e+06

```
Summary for Scenario 4:
Summary for Far East from to EU (Scenario 4)
       Total Revenue  Total Revenue per Day  Utilization Rate Outbound  \
count   2.500000e+05           2.500000e+05              250000.000000
mean    5.446017e+09           9.661408e+07                   0.978864
std     7.258518e+08           1.425085e+07                   0.011956
min     4.129094e+09           6.641526e+07                   0.958966
25%     4.819717e+09           8.513315e+07                   0.968291
50%     5.446079e+09           9.628176e+07                   0.979056
75%     6.072980e+09           1.073789e+08                   0.988888
max     6.783629e+09           1.336196e+08                   0.999964

       Utilization Rate Return  Freight Rate per TEU Outbound  \
count            250000.000000                  250000.000000
mean                  0.955861                     238.840878
std                   0.004403                      31.886467
min                   0.948534                     182.406937
25%                   0.951968                     213.354174
50%                   0.955932                     240.296723
75%                   0.959553                     265.455348
max                   0.963632                     295.851640

       Freight Rate per TEU Return  Average Transit Days Outbound  \
count                250000.000000                  250000.000000
mean                   2314.286789                      63.302324
std                     326.470896                       3.837542
min                    1762.141426                      56.709654
25%                    2020.102222                      60.231413
50%                    2325.689967                      63.182263
75%                    2599.855721                      66.297285
max                    2862.596271                      70.171917

       Average Transit Days Return  Additional Empties Outbound  \
count                250000.000000                250000.000000
mean                     56.268732                 21241.559422
std                       3.411148                 10554.241618
min                      50.408581                  3677.631066
25%                      53.539034                 11909.086498
50%                      56.162012                 21411.320145
75%                      58.930920                 30089.758072
max                      62.375037                 39867.283991

       Additional Empties Return  Loss of Revenue per Day  \
count              250000.000000             2.500000e+05
mean                21241.559422             8.744229e+05
std                 10554.241618             4.585670e+05
min                  3677.631066             1.053326e+05
25%                 11909.086498             4.768060e+05
50%                 21411.320145             8.547089e+05
75%                 30089.758072             1.223571e+06
max                 39867.283991             2.229196e+06

       Total Loss of Revenue due to Repositioning  Adjusted Total Revenue  \
count                                2.500000e+05            2.500000e+05
mean                                 4.911976e+07            5.411069e+09
std                                  2.553124e+07            7.255260e+08
min                                  6.485550e+06            4.112384e+09
25%                                  2.686376e+07            4.784358e+09
50%                                  4.820259e+07            5.411033e+09
75%                                  6.890688e+07            6.038520e+09
max                                  1.141045e+08            6.720921e+09

       Adjusted Total Revenue per Day
count                    2.500000e+05
mean                     9.532882e+07
std                      1.424778e+07
min                      6.444629e+07
25%                      8.385107e+07
50%                      9.501354e+07
75%                      1.060893e+08
max                      1.316907e+08
```

Summary for Africa from to EU (Scenario 4)

	Total Revenue	Total Revenue per Day	Utilization Rate Outbound \
count	2.500000e+05	2.500000e+05	250000.000000
mean	3.185685e+08	8.581120e+06	0.808979
std	3.268565e+07	1.035939e+06	0.026347
min	2.354628e+08	5.766961e+06	0.762482
25%	2.941837e+08	7.820756e+06	0.786890
50%	3.183022e+08	8.542288e+06	0.808555
75%	3.429407e+08	9.296274e+06	0.832276
max	4.082282e+08	1.218238e+07	0.852825

	Utilization Rate Return	Freight Rate per TEU Outbound \
count	2.500000e+05	250000.000000
mean	6.988014e-01	2022.446605
std	5.390144e-13	273.155588
min	6.988014e-01	1554.646912
25%	6.988014e-01	1790.086239
50%	6.988014e-01	2024.705754
75%	6.988014e-01	2237.990195
max	6.988014e-01	2525.032867

	Freight Rate per TEU Return	Average Transit Days Outbound \
count	250000.000000	250000.000000
mean	1171.057752	36.498596
std	160.734157	2.273995
min	887.433751	32.556995
25%	1040.958633	34.522238
50%	1173.231948	36.664998
75%	1304.193585	38.449249
max	1440.937294	40.293426

	Average Transit Days Return	Additional Empties Outbound \
count	250000.000000	250000.000000
mean	38.853344	-7080.519807
std	2.420705	3518.080539
min	34.657446	-13289.094664
25%	36.749480	-10029.919357
50%	39.030482	-7137.106715
75%	40.929846	-3969.695499
max	42.893002	-1225.877022

	Additional Empties Return	Loss of Revenue per Day \
count	250000.0	2.500000e+05
mean	0.0	-3.981725e+05
std	0.0	2.088965e+05
min	0.0	-1.025283e+06
25%	0.0	-5.573982e+05
50%	0.0	-3.889753e+05
75%	0.0	-2.173189e+05
max	0.0	-4.745543e+04

	Total Loss of Revenue due to Repositioning
count	2.500000e+05
mean	-1.444890e+07
std	7.514836e+06
min	-3.354611e+07
25%	-2.027652e+07
50%	-1.417720e+07
75%	-7.890116e+06
max	-1.907173e+06

```
Summary for Latin America from to EU (Scenario 4)
       Total Revenue  Total Revenue per Day  Utilization Rate Outbound  \
count   2.500000e+05           2.500000e+05              250000.000000
mean    6.096112e+08           2.177867e+07                   0.782614
std     5.990189e+07           2.557553e+06                   0.010924
min     4.607951e+08           1.495805e+07                   0.763336
25%     5.659912e+08           1.991220e+07                   0.773456
50%     6.096126e+08           2.169604e+07                   0.782439
75%     6.531784e+08           2.354735e+07                   0.792274
max     7.606517e+08           3.002986e+07                   0.800794

       Utilization Rate Return  Freight Rate per TEU Outbound  \
count             2.500000e+05                  250000.000000
mean              7.814990e-01                    1089.725340
std               2.173488e-12                     151.349951
min               7.814990e-01                     827.663290
25%               7.814990e-01                     957.356030
50%               7.814990e-01                    1088.645684
75%               7.814990e-01                    1222.847386
max               7.814990e-01                    1340.572541

       Freight Rate per TEU Return  Average Transit Days Outbound  \
count                250000.000000                  250000.000000
mean                   1397.153731                      31.737276
std                     187.960003                       1.879171
min                    1054.404053                      28.354636
25%                    1236.497574                      30.142511
50%                    1415.858630                      31.848890
75%                    1562.609585                      33.362001
max                    1711.563845                      35.099803

       Average Transit Days Return  Additional Empties Outbound  \
count                250000.000000                250000.000000
mean                     25.860003                 -7080.519807
std                       1.531176                  3518.080539
min                      23.103777                -13289.094664
25%                      24.560564                -10029.919357
50%                      25.950947                 -7137.106715
75%                      27.183853                 -3969.695499
max                      28.599839                 -1225.877022

       Additional Empties Return  Loss of Revenue per Day  \
count                   250000.0            250000.000000
mean                         0.0           -243293.474111
std                          0.0            127689.207625
min                          0.0           -622319.058002
25%                          0.0           -340798.524768
50%                          0.0           -237647.355727
75%                          0.0           -132604.477754
max                          0.0            -29062.957795

       Total Loss of Revenue due to Repositioning
count                                2.500000e+05
mean                                -7.687736e+06
std                                  3.998468e+06
min                                 -1.785109e+07
25%                                 -1.078962e+07
50%                                 -7.541092e+06
75%                                 -4.205399e+06
max                                 -1.014440e+06
```

Summary for North America from to EU (Scenario 4)

	Total Revenue	Total Revenue per Day	Utilization Rate Outbound
count	2.500000e+05	2.500000e+05	250000.000000
mean	1.392419e+09	7.056950e+07	0.888551
std	1.671699e+08	9.493458e+06	0.004645
min	1.052154e+09	4.836594e+07	0.880353
25%	1.249379e+09	6.311325e+07	0.884656
50%	1.392648e+09	7.030791e+07	0.888476
75%	1.535599e+09	7.756773e+07	0.892658
max	1.732745e+09	9.738390e+07	0.896281

	Utilization Rate Return	Freight Rate per TEU Outbound
count	2.500000e+05	250000.000000
mean	8.217986e-01	1819.840585
std	2.937323e-12	248.685621
min	8.217986e-01	1378.619991
25%	8.217986e-01	1606.317699
50%	8.217986e-01	1829.445804
75%	8.217986e-01	2037.299386
max	8.217986e-01	2237.334467

	Freight Rate per TEU Return	Average Transit Days Outbound
count	250000.000000	250000.000000
mean	833.233011	20.001579
std	119.264213	1.228119
min	641.064882	17.859827
25%	729.808901	18.939999
50%	828.039377	19.986173
75%	938.141810	21.080824
max	1038.348472	22.079932

	Average Transit Days Return	Additional Empties Outbound
count	250000.000000	250000.000000
mean	18.825015	-7080.519807
std	1.155877	3518.080539
min	16.809249	-13289.094664
25%	17.825882	-10029.919357
50%	18.810516	-7137.106715
75%	19.840775	-3969.695499
max	20.781113	-1225.877022

	Additional Empties Return	Loss of Revenue per Day
count	250000.0	2.500000e+05
mean	0.0	-6.437980e+05
std	0.0	3.378935e+05
min	0.0	-1.633210e+06
25%	0.0	-9.014426e+05
50%	0.0	-6.295396e+05
75%	0.0	-3.507267e+05
max	0.0	-7.664775e+04

	Total Loss of Revenue due to Repositioning
count	2.500000e+05
mean	-1.281066e+07
std	6.662034e+06
min	-2.974348e+07
25%	-1.796968e+07
50%	-1.256148e+07
75%	-6.998823e+06
max	-1.690258e+06

Appendix L

Statistical Summary from Alternative 1 (Seasonality)

Scenario 1 - Far East from to EU:

	Full Year Total Revenue	Full Year Revenue per Day
count	5.000000e+02	5.000000e+02
mean	5.503432e+09	9.750732e+07
std	1.403977e+08	2.986351e+06
min	5.128299e+09	8.987021e+07
25%	5.400425e+09	9.529415e+07
50%	5.501508e+09	9.744244e+07
75%	5.601248e+09	9.943741e+07
max	5.847606e+09	1.064728e+08

===

Scenario 1 - Africa from to EU:

	Full Year Total Revenue	Full Year Revenue per Day
count	5.000000e+02	5.000000e+02
mean	3.238635e+08	8.721045e+06
std	5.592982e+06	2.312276e+05
min	3.074204e+08	7.958320e+06
25%	3.200738e+08	8.577044e+06
50%	3.240305e+08	8.731202e+06
75%	3.277994e+08	8.877640e+06
max	3.381272e+08	9.297542e+06

===

Scenario 1 - Latin America from to EU:

	Full Year Total Revenue	Full Year Revenue per Day
count	5.000000e+02	5.000000e+02
mean	5.942288e+08	2.134621e+07
std	2.129575e+07	8.588703e+05
min	5.425375e+08	1.878842e+07
25%	5.778697e+08	2.074853e+07
50%	5.941518e+08	2.129797e+07
75%	6.120990e+08	2.195722e+07
max	6.425139e+08	2.365936e+07

===

Scenario 1 - North America from to EU:

	Full Year Total Revenue	Full Year Revenue per Day
count	5.000000e+02	5.000000e+02
mean	1.409984e+09	7.148135e+07
std	2.889617e+07	1.931160e+06
min	1.331577e+09	6.661565e+07
25%	1.389884e+09	7.016470e+07
50%	1.410760e+09	7.153287e+07
75%	1.429398e+09	7.289555e+07
max	1.519789e+09	8.066201e+07

Scenario 2 - Far East from to EU:

	Full Year Total Revenue	Full Year Revenue per Day
count	5.000000e+02	5.000000e+02
mean	5.516810e+09	9.770087e+07
std	1.358651e+08	2.924294e+06
min	5.155044e+09	8.942229e+07
25%	5.425540e+09	9.587663e+07
50%	5.518057e+09	9.745438e+07
75%	5.609921e+09	9.970191e+07
max	5.900189e+09	1.055352e+08

===

Scenario 2 - Africa from to EU:

	Full Year Total Revenue	Full Year Revenue per Day
count	5.000000e+02	5.000000e+02
mean	3.406407e+08	9.198740e+06
std	6.171103e+06	2.307042e+05
min	3.200180e+08	8.402849e+06
25%	3.364098e+08	9.040124e+06
50%	3.407091e+08	9.182089e+06
75%	3.449981e+08	9.355592e+06
max	3.601818e+08	9.892360e+06

===

Scenario 2 - Latin America from to EU:

	Full Year Total Revenue	Full Year Revenue per Day
count	5.000000e+02	5.000000e+02
mean	5.873104e+08	2.111169e+07
std	2.130369e+07	8.419026e+05
min	5.310181e+08	1.813397e+07
25%	5.703275e+08	2.052712e+07
50%	5.882568e+08	2.113622e+07
75%	6.040739e+08	2.168431e+07
max	6.368483e+08	2.331183e+07

===

Scenario 2 - North America from to EU:

	Full Year Total Revenue	Full Year Revenue per Day
count	5.000000e+02	5.000000e+02
mean	1.408226e+09	7.138518e+07
std	2.911299e+07	1.955424e+06
min	1.327448e+09	6.628009e+07
25%	1.390129e+09	7.007465e+07
50%	1.408414e+09	7.132548e+07
75%	1.427077e+09	7.273691e+07
max	1.488768e+09	7.857960e+07

Scenario 3 - Far East from to EU:

	Full Year Total Revenue	Full Year Revenue per Day
count	5.000000e+02	5.000000e+02
mean	5.498379e+09	9.708850e+07
std	1.383745e+08	2.981213e+06
min	5.120815e+09	8.790997e+07
25%	5.407911e+09	9.506607e+07
50%	5.496508e+09	9.711910e+07
75%	5.596582e+09	9.908329e+07
max	5.873797e+09	1.062905e+08

==

Scenario 3 - Africa from to EU:

	Full Year Total Revenue	Full Year Revenue per Day
count	5.000000e+02	5.000000e+02
mean	3.408402e+08	9.204635e+06
std	6.167337e+06	2.329365e+05
min	3.226285e+08	8.546194e+06
25%	3.366066e+08	9.040885e+06
50%	3.407381e+08	9.203478e+06
75%	3.452768e+08	9.358749e+06
max	3.601710e+08	9.833707e+06

==

Scenario 3 - Latin America from to EU:

	Full Year Total Revenue	Full Year Revenue per Day
count	5.000000e+02	5.000000e+02
mean	5.962836e+08	2.140561e+07
std	2.024739e+07	7.983679e+05
min	5.492955e+08	1.932046e+07
25%	5.811362e+08	2.081294e+07
50%	5.965999e+08	2.137417e+07
75%	6.109058e+08	2.192528e+07
max	6.441430e+08	2.384674e+07

==

Scenario 3 - North America from to EU:

	Full Year Total Revenue	Full Year Revenue per Day
count	5.000000e+02	5.000000e+02
mean	1.394469e+09	7.060173e+07
std	2.690836e+07	1.828988e+06
min	1.319775e+09	6.561779e+07
25%	1.376678e+09	6.937746e+07
50%	1.393162e+09	7.054397e+07
75%	1.413141e+09	7.180379e+07
max	1.464187e+09	7.641470e+07

Scenario 4 - Far East from to EU:

	Full Year Total Revenue	Full Year Revenue per Day
count	5.000000e+02	5.000000e+02
mean	5.215550e+09	9.669222e+07
std	1.366415e+08	2.948816e+06
min	4.876254e+09	8.948532e+07
25%	5.115798e+09	9.456301e+07
50%	5.212081e+09	9.671735e+07
75%	5.314324e+09	9.879042e+07
max	5.598839e+09	1.058309e+08

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Scenario 4 - Africa from to EU:

	Full Year Total Revenue	Full Year Revenue per Day
count	5.000000e+02	5.000000e+02
mean	3.351591e+08	9.039816e+06
std	5.959347e+06	2.230561e+05
min	3.190134e+08	8.412775e+06
25%	3.313481e+08	8.896129e+06
50%	3.347942e+08	9.034802e+06
75%	3.391595e+08	9.205641e+06
max	3.580968e+08	9.637046e+06

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Scenario 4 - Latin America from to EU:

	Full Year Total Revenue	Full Year Revenue per Day
count	5.000000e+02	5.000000e+02
mean	5.915068e+08	2.124816e+07
std	2.103316e+07	8.506033e+05
min	5.398834e+08	1.905676e+07
25%	5.754011e+08	2.062457e+07
50%	5.917826e+08	2.126352e+07
75%	6.078535e+08	2.182218e+07
max	6.419445e+08	2.350686e+07

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Scenario 4 - North America from to EU:

	Full Year Total Revenue	Full Year Revenue per Day
count	5.000000e+02	5.000000e+02
mean	1.405167e+09	7.114508e+07
std	2.753268e+07	1.955434e+06
min	1.325214e+09	6.485549e+07
25%	1.388083e+09	6.981999e+07
50%	1.404850e+09	7.106481e+07
75%	1.423029e+09	7.242649e+07
max	1.474156e+09	7.684061e+07