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COST ACCOUNTING TECHNIQUES

THE CASE OF SHIPPING INDUSTRY

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Διπλωματική Εργασία

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Περίληψη

Η παρούσα διπλωματική εργασία εξετάζει τη διεθνή διάσταση της βιομηχανίας ναυπήγησης, με έμφαση στα εμπλεκόμενα μέρη και το κόστος κατά τη διάρκεια ενός έργου κατασκευής νέου πλοίου. Η εργασία διερευνά επίσης τις ανησυχίες και τις προοπτικές τόσο των πλοιοκτητών όσο και των ναυπηγείων σχετικά με την κατασκευή νέων πλοίων και ιδιαιτέρως τα στοιχεία κόστους που εμπλέκονται. Από την πλευρά του πλοιοκτήτη, η λήψη αποφάσεων περιλαμβάνει μια προσεκτική και μεθοδική αξιολόγηση διαφόρων κρίσιμων παραγόντων, όπως η υφιστάμενη και η προβλεπόμενη κατάσταση της αγοράς, η τεχνολογία και οι τεχνικές προδιαγραφές, η διαθεσιμότητα χρηματοδότησης, τυχόν περιορισμοί προϋπολογισμού και η λειτουργική κερδοφορία. Όλα τα εμπλεκόμενα μέρη, όπως οι πλοιοκτήτες, τα ναυπηγεία, οι διεθνείς οργανισμοί και οι ρυθμιστικές αρχές, οι νηογνώμονες και τα χρηματοπιστωτικά ιδρύματα λαμβάνονται υπόψη, καθώς διαδραματίζουν σημαντικό ρόλο στη διαδικασία ναυπήγησης. Επιπλέον, σημαντικά έγγραφα όπως η σύμβαση του παραγγελθέντος πλοίου μεταξύ του πλοιοκτήτη, του εξουσιοδοτημένου μεσίτη και του ναυπηγείου, οι συμφωνίες των προδιαγραφών, τα χρηματοδοτικά έγγραφα, τα συμβόλαια και τα τεχνικά σχέδια εξετάζονται ρητά για τις νομικές επιπτώσεις που εμπεριέχουν. Από την πλευρά του ναυπηγείου, η εργασία εξετάζει τις προκλήσεις της εκτίμησης κόστους, λαμβάνοντας υπόψη διαφορετικές μεθόδους και τεχνικές κόστους, που χρησιμοποιούνται ευρέως από πολλούς οργανισμούς. Διαφορετικά στοιχεία κόστους, όπως υλικά, εργασία, γενικά έξοδα καθώς και η συμμόρφωση με κανονισμούς, αναλύονται για να προσδιοριστεί η επίδρασή τους στο συνολικό κόστος ενός νέου πλοίου. Επιπλέον, εξετάζονται οι τεχνικές και οι μέθοδοι μεταβλητού κόστους κατά τη διάρκεια της διαδικασίας ναυπήγησης. Η εργασία στοχεύει στην παροχή βαθύτερης κατανόησης της αγοράς της ναυτιλιακής βιομηχανίας και των παραγόντων κόστους που επηρεάζουν την απόφαση για τη ναυπήγηση. Οι απόψεις τόσο των πλοιοκτητών όσο και των ναυπηγείων λαμβάνονται υπόψη στην κτήση νέων πλοίων. Τέλος, η εργασία αναφέρεται στις μεθόδους μεταβλητού κόστους για τον υπολογισμό και την εκτίμηση του κόστους, ένας βασικός δείκτης αποτελεσματικής απόδοσης και κερδοφόρας λειτουργίας.

Abstract

This thesis explores the international dimension of the shipbuilding industry, with a focus on the parties and costs involved during a new build project. The thesis also examines the concerns and perspectives of both shipowners and shipyards regarding the construction of new build vessels and particularly the cost elements involved. From a shipowner's point of view, the decision-making involves a vigilant and thoughtful evaluation of different critical factors, such as the existing and the forecasted market condition, the technology and the design specifications, the availability of financing, any budget restrictions, and the operating profitability. All parties involved, such as the shipowners, the shipyards, the international organizations and regulators, the classification societies, and the financing institutions are taken into account since they play a significant role during the shipbuilding process. Moreover, important documents such as the ordered ship contract between the shipowner, the authorized broker, and the shipyard, the specification agreements, the financing documentation and contracts, and the technical design documents are reviewed explicitly for the legal implications involved.

From a shipyard's point of view, the thesis examines the challenges of cost estimation, taking into consideration different cost methods and techniques projects, used widely by many organizations. Different cost elements such as materials, labor, overheads, and regulatory compliance are analyzed to determine their influence on the total cost of a new building vessel. Additionally, variable cost accounting techniques and methods are examined during the shipbuilding process.

The thesis aims to provide a deeper understanding of the shipping industry market and the cost factors affecting the shipbuilding decision. The insights of both shipowners and shipyards are taken into consideration in the development of newbuild vessels. Finally, the thesis refers to the variable cost methods for the calculation and the estimation of the cost element, an essential indicator of effective performance and profitable operation.

Introduction

The present study explores the international aspect of the shipbuilding industry, focusing mainly on the key parties involved and the costs involved during a new build project. Our study extends current literature by examining both shipowners' and shipyards' points of view with regard to a new build order, offering a better understanding of the critical cost elements that shape decision-making in newbuild vessel projects. The motivation for this study arises from the need to examine different factors such as material, labor, and compliance costs while ensuring profitability and meeting the current technological and regulatory standards of the shipbuilding industry. This study contributes to the literature by assessing key cost elements such as materials, labor, overheads, and regulatory compliance, while also taking into consideration the legal framework that govern shipbuilding agreements between shipowners, shipyards, and other stakeholders. By taking into account the shipowners' concerns regarding financial market conditions, available financing, and design specifications with shipyards' considerations related to cost estimation and project execution, the study provides a holistic view of the cost structures and financial dynamics in this shipping industry. The implications of these findings are significant for the improvement of cost management practices, leading to a more efficient decision-making resulting eventually to a competitive advantage in the shipbuilding process. Moreover, the study offers a detailed examination of variable cost accounting methods and techniques. Additionally, the study proceeds with an analysis of traditional versus modern techniques and with the examination of their implications highlighting the significance for effective performance and profitability in ship construction projects.

Section 2 reviews the literature on the shipbuilding industry, providing a comprehensive overview of the significance of the shipping industry in global trade and in the efficient transportation of good and commodities around the globe. In this section maritime economics and the factors of demand and supply are thoroughly examined since they are interrelated to the shipping industry as a whole.

Section 3 focuses on the main commodities traded globally, such as oil, coal, iron ore and grains, necessary to end consumers, industries, national economies and infrastructure projects. Main ports are also discussed serving as key hubs around the world for vessels operations and cargo transportation.

Section 4 discusses the evolution of vessels from early vessels to today's sophisticated types, the main vessel types, and their classification according to dimensions and the

cargo types they carry. The type, the dimensions, and the technology of a vessel are all critical factors taken into consideration by a shipowner before deciding to invest and place a new order.

Section 5 delves into the shipowner's perspective, highlighting the factors influencing their decision-making. The phases of the shipping cycles and the market conditions in general affect shipowners' decisions, their financing availability, and their profitability. The consideration of the market phases, the available forecasts and information from the market are all important tools to shipowners assisting their decision-making aiming at risk hedging and profits maximization.

Section 6 focuses on the shipyard's perspective, exploring the challenges of cost estimation and the different cost methods and techniques employed. Key cost elements, such as materials, labor, overheads, and regulatory compliance, are analyzed in detail. This section also examines the legal and contractual documents, including shipbuilding contracts and technical design agreements.

Section 7 presents an analysis of variable cost accounting methods and techniques used in the shipbuilding process, as well as their impact on cost estimation and project performance. The cost techniques to be followed are examined and aligned with the company's financial goals, the project's complexity and the operational environment. A company can select the most appropriate cost technique and method to effectively estimate and control a project's cost and ensure profitability.

Finally, Section 8 concludes the paper by summarizing the key findings and discussing their implications for improving cost management and decision-making in the shipbuilding industry. The budget versus actual comparison is discussed to highlight the importance of effective financial management followed by a company. The comparison is vital for decision-making, cost-control to ensure viability and mitigate financial risks in projects.

Completing this thesis was a process requiring systematic study and analysis of modern methods and techniques in the shipbuilding industry. Throughout this journey, the support and guidance of certain individuals and institutions proved essential.

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1. The International Aspect of Shipping

Shipping constitutes one of the most pivotal sectors globally and is an integral component of international trade. With over two-thirds of the Earth's surface covered in water, ships facilitate a staggering 95% of global trade. The demand for ships stems from the need to efficiently transport goods across the globe in a punctual and economically prudent manner. Economists argue that the demand for shipping is a derived demand and it highly interacts with the factors of supply and demand for final products and services among end consumers. The international dimension of shipping relies mostly upon the interaction of individuals and corporations around the globe. Shipping necessitates communication, negotiation, and contractual agreements between parties hailing from diverse linguistic backgrounds and legal jurisdictions. The contractual agreements between two or more entities pertain to the transportation and sale of goods or the provision of services. The contracts encompass certain terms and conditions and are typically governed by English Law. Such terms are referred to as the Incoterms published by the International Chamber of Commerce (ICC). Incoterms are widely used in international trading activity, specifying duties, rights, and responsibilities of the parties involved, and serve as widely adopted standards within international trade (Institute of Chartered Shipbrokers, 2016).

1.1 The Importance of Shipping

The significance of shipping extends beyond mere economic activity, profoundly impacting daily life. Owing to their large size, vessels can transport substantial quantities of raw materials, commodities, products, and manufactured goods over vast distances securely and cost-effectively. The importance of shipping lies in the fact that economies of scale are achieved, as costs are proportionally distributed across the cargo carried by a vessel. This confers a competitive advantage upon companies with expansive fleets when they increase the scale of their operations. Moreover, large vessels enable companies to mitigate their operational costs, particularly fuel expenses, which are considered to be one of the substantial costs in the shipping industry. Ships can carry vast cargo volumes using less fuel consumption per unit of cargo, offering a sustainable mode of transportation by reducing the average cost and achieving economies of scale. As a consequence, companies enhance profitability through the reduction of substantial expenses.

1.2 Maritime Economics

The trading activity by sea is based on the supply and demand dynamics, influenced by various determinants. As per Martin Stopford (Stopford, 2009) ten variables underpin the shipping market model: demand affected by the world economic condition, seaborne commodity trades, average haul, random shocks, and transport costs, while supply is affected by the existing world fleet, the fleet productivity, the shipbuilding production, the scrapping and losses, and the freight revenue.

1.2.1 The Demand Factor

The world economy, in particular, is affected by different factors including global trends, market conditions, environmental and health considerations, and geopolitical factors. Factors such as international trade agreements and tariffs exert a notable influence on the transportation of commodities worldwide and the trading activity between countries. Financial markets are highly related to stock exchange fluctuations and events related to changes in interest and currency exchange rates. Their volatility can have profound implications with either negative or positive effects on trading activities and the broader global economy, thereby influencing business decision-making.

The basic indicators for the examination of the financial condition of countries are the Gross Domestic Product (GDP) and the Gross National Product (GNP) index. Both key economic indicators provide insights into the financial health of nations. The GDP is concerned with the measurement of a country's economic activity taking into consideration the monetary value of finalized goods and services produced, at a certain period. The GNP measures the output of a country's residents irrespective of their business or physical location. Since GDP is expressed in nominal prices, adjustments need to be made for inflation. for inflation. For someone to be able to compare two or more periods using the GDP indicator, which might at a certain point in time show a high output, one should examine whether this output is related to real economic growth or is a result of higher prices deriving from inflation. For that adjustment tools such as price deflator are used. By using the real GDP index, important information can be obtained regarding both a specific country's economy and the international economic scene. A high GDP serves as a sign of a healthy and growing economy while the

opposite applies when it is decreasing, showing signs of a recession usually as a result of a crisis or a market shock.

Additionally, environmental conditions and international maritime laws significantly impact shipping industry activities, while maritime policies also exert a wide influence over industry practices. Over recent decades, the industry has undergone substantial regulation and governance by international organizations such as the International Maritime Organization (IMO), a United Nations agency establishing rules and conditions governing the operation of a shipping company and vessels, to mitigate and prevent both marine and atmospheric pollution from ships. Operational and technological development is now imperative for ensuring the safe navigation of vessels with international conventions encompassing regulations covering various areas of environmental protection. Furthermore, regulations pertaining to vessel construction have been implemented to promote energy-efficient ship design.

Decarbonization is a major issue that has emerged as a pressing concern. Proactive measures are being taken by most shipping companies, including the construction of new building ships or significant and often high-cost alterations to be made to the existing ones. Classification societies, organizations involved in the development and application of design and technical standards of vessels, and are closely collaborating with the IMO to foster a more sustainable and environmentally friendly shipping industry.

Additionally, seaborne commodity trade is related mainly to commodity prices. The prices of the most significant ones such as oil, iron ore, coal, and grains, may lead to either an increased or a minimized trading activity impacting the shipping market activity. The shipping industry is also affected by the seasonality factors mainly related to grains and other agricultural commodities. For instance, severe weather conditions might cause a lack of sufficient quantity of a commodity and would result in high prices since the demand for the respective commodity would increase while the supply would be limited.

Regarding the average haul factor, the total carrying capacity of vessels and the number of operating ships can affect the dynamics of supply and demand. The more the number of fleets operating at a certain period, the less the demand for new vessels, since there is a sufficient number of vessels covering the existing demand, leading eventually to oversupply. To look into the seaborne trade, which is related to the demand factor in shipping, aspects such as the oil prices, the seasonality effect of certain commodities

such as grains, and the higher demand for steel as a consequence of the increasing activity of infrastructure, must be taken into account.

Oil prices are characterized by volatility and fluctuations and are mainly determined by the oil exporting countries' decisions, controlling the production or the cuts of oil. In the event of an oil price boom, the company's operational and trading costs would be impacted by the escalation of transportation costs through the rise of fuel/bunker costs. That rise would not only result in higher transportation costs but would also result in increased final product prices for the end consumers. In the shipping industry, oil prices are key determinants of freight rates, an element thoroughly examined by shipping companies since they base their revenue and viability on them. Shocks to the oil supply and demand, impact freight rates urging the shipping companies to take corrective actions by adjusting and trying to cut the transportation costs aiming to prevent their profitability. When oil prices rise the effect is spared worldwide affecting the import and export activity of countries and the private consumer's consumption of products. Oil production and oil prices are mainly determined by oil exporting countries and are correlated to the movement of goods by ships either negatively or positively depending on the existing oil prices.

As a random shock, we could use the example of the COVID-19 virus, an unpredictable global health situation with impact both socially and economically. The virus led to many businesses suffering and eventually closing resulting also in a disruption of the global supply chain. For instance, the demand for many types of vessels such as tanker vessels was reduced due to the decline in oil demand consumption which led to these particular types of vessels being used as storage units instead. Other disturbances such as wars and financial crises can affect the world economy at a certain period. In the event of war, apart from the loss and threat to human life, rising inflation will result in high levels of poverty and economic distress. A financial crisis such as a stock market crash may have regional or worldwide effects.

Finally, transportation costs such as fuel and bunker expenses are of great importance considering that they are one of the highest components of operating costs. The volatility of oil prices is always taken into consideration and influences the decisions of a ship operator. Oil Crises like for example the 1973 crisis of the Organization of the Petroleum Exporting Countries (OPEC) where member countries announced the implementation of an embargo against the countries supporting the Israels in the Yom Kippur War, resulted in high prices of oil due to lack of sufficient supply and as a

consequence a global recession considering that oil is the most significant commodity worldwide.

The cyclical nature of businesses and trade activity is of major significance when examining the demand factor. All the elements mentioned above contribute to distractions of the market function leading to peaks and troughs that derive from unforeseen circumstances.

1.2.2 The Supply factors

The shipping industry is the supplier of ships used for the transportation of goods around the globe economically and efficiently. Cargoes from all over the world are moved daily from one area to another aiming to provide accessibility of commodities and final products to end consumers. The output of shipping is measured by taking into consideration the available capacity of ships and how much cargo a ship can carry over a certain distance. This is called the tone-mile measurement over a specific period.

The supply factor in shipping can be affected by the stock of the existing vessels operating in the market and by the way ships are operated and employed.

The cyclical nature of business is a key indicator for parties involved in the industry. Ship owners, charterers, and financial organizations are the basic decision-makers that influence the supply of vessels. After the examination of the existing economic conditions, decision-makers are the ones who will decide if the number of existing vessels is sufficient to cover the supply of goods and commodities, whether new building orders should take place, or if there is an oversupply of vessels affecting the freight revenues, that would force them to the scrapping or laying off decision of the extra vessels.

There are different ways where the existing fleet can be used to alter the supply factor. Firstly, a ship can be used as a storage facility, for example, tanker vessels at periods of oversupply can be used as oil storage facilities instead of being used in the transportation of oil barrels or a bulk cargo-carrying vessel can be used as a storage for grains after the harvesting period.

Secondly, decisions including laying up a vessel may be used to change the supply output. A shipowner decides to locate the ship in a safe anchorage, a small number of crew members is kept on the ship to maintain and monitor the ship’s performance and the ship is being kept out of the trading market. Once the demand for ships recovers

and the market is in the necessity of vessels, a shipowner can activate the ship again, at a cost though, to make it fully operational.

A third way to affect the supply of vessels in the market is by changing the speed of the vessels and opting for the low steaming practice, a very common choice by many shipowners. If speed is minimized, then a voyage held by a vessel will take more time or days to be concluded while fuel consumption will also be minimized. This will eventually result in fewer vessels being available in the market for the transportation of cargo since vessels will be already engaged in other trading activities. In that case, there will be a lack of vessels available to engage in new cargo transportation, while the number of the existing fleet in the market remains the same. Fourth, the supply factor can be affected by the imbalance in a ship's round voyage. A ship may travel fully laden in the one leg of the voyage while it might travel in ballast after discharging in the second leg. This leads to cargo space and ship's capacity being lost. A way to modify this discrepancy is if a new voyage is fixed in advance to prevent the ship from traveling in ballast, to benefit from the carrying space of a ship without altering the supply side of the existing number of ships.

Finally, another factor that can be used to alter the way the supplied number of vessels are being used is to reduce the period a vessel stays in a port, or a terminal compared to the time it sails at sea. By reducing port time, a vessel is available more frequently and can take over more operations although this element is not necessarily controlled by the shipowner considering the congestion situation at a port or unforeseen weather conditions.

About the supply of new vessels and the shipbuilding activity, the type of vessels to be built is highly considered. Not all markets within the shipping industry react similarly to events affecting the world economy. On the one hand, an event might have positive effects on a company operating a tanker vessel, and on the other hand, the same event might result in negative consequences for a company operating a container ship. That will have as a result for an owner ordering a new vessel to think carefully about which type of vessel, they need to order to have a profitable business in the existing circumstances.

Moreover, the technological aspect of the vessels is of essential consideration. Due to the existing regulations vessels have to be built under certain conditions and as per the classification societies' instructions. The fact that obsolete vessels cannot compete leads

to either new building orders from the shipowners that have the capability of financing one or to the scrapping decision by taking the ship out of the market.

Regarding the productivity of each ship, the most significant elements are the speed, the consumption, and the capacity in terms of deadweight. The overall performance of a vessel is monitored by the shipping companies since it affects the financial position and the revenues expected by each vessel operator. Operational costs such as crew costs, maintenance and repairs, and bunkers are of major importance to a shipping company, trying to balance costs and revenues aiming to profit.

Concerning the scrapping of vessels, the earnings of a company and factors such as the age and the technological condition of a vessel are taken into consideration.

An obsolete vessel will not be able to compete with new ones and this will eventually result in increased costs of maintenance and repairs that might be higher than the total earnings from the operation of the same ship. When a ship reaches the end of its useful life it requires higher costs and expenditures to remain in a safe operational condition. Once the second-hand value of a ship drops lower than the recycling value then the scrapping decision is inevitable.

Moreover, technologically obsolete ships are being sent to recycling as a result of environmental regulations towards a more sustainable and environmentally friendly shipping industry. Old ships are forced out of the industry mainly because there is a lack of profitability by the employment of the same.

Finally, decision-makers in the industry will be motivated by the most important factor. Freight revenues are the most significant element for the viability of a shipping company that could either own or charter a vessel. Freight rates are the result of existing dynamics in the market, the financial position of key players, and their investing decisions. Freight revenue is the basic source of income in the shipping sector which can be generated by the operation of a ship. When freight rates are high investors tend to order new vessels to take advantage of the profitable market conditions. That will eventually lead in the future to an oversupply of vessels more than sufficient to serve the demand of the market. As a result, freight rates will start falling, harshening the financial position of the parties involved, leading to a sale, a lay-up, or the scrapping of a ship.

2. International Trade

Ships are widely used as providers of transportation services to companies that produce or seek either raw materials or manufactured products. Transportation via ships is considered a low-cost service that facilitates trading around the globe for transporting different types of cargo.

Commodities play a pivotal role in maritime trade, encompassing raw materials, agricultural and food products, manufactured goods, construction goods, and energy products.

Raw materials are mostly traded in their initial form to be used after certain processes and can be transported in dry bulk or liquid bulk form depending on their nature.

2.1 The main commodities

Notable commodities include crude oil, coal, iron ore, and grains, each vital to industrial production, energy generation, and global food supply chains.

2.1.1 Oil

One of the most significant and widely traded commodities is crude oil. Crude oil is a natural, non-refined product found under the surface of the Earth. It consists of organic materials and hydrocarbon deposits which after years of undersurface processes have resulted in the production of fossil fuel. It is one of the most vital energy production resources which is refined to further petroleum products that are used in heating, transportation, and construction such as gasoline, naphtha kerosene, and other gaseous oils such as Liquefied Natural Gas (LNG) and Liquified Petroleum Gas (LPG). Both crude oil and its products are usually stored in tanks close to the areas of production to serve the end consumer by being ready to be transported and carried by trucks, trains, or pipelines. Historically Middle Eastern countries used to rank first among the major exporters of oil with Saudi Arabia being in the top as a member of the Organization of the Petroleum Exporting Countries (OPEC). However, currently the United States is also considered one of the biggest exporting countries of oil followed by Canada and Russia serving the global demand.

2.1.2 Coal

Apart from oil and its products, another significant energy-producing commodity is coal. Coal is a combustible rock, a mixture of carbon and hydrocarbons, and is one of the most abundant fossil fuels in nature. It is a major energy source for the industrial and construction activities of countries. There are different types of coal such as steaming or thermal coal and coking or metallurgical coal. Steam or thermal coal upon burning generates steam for the production of electricity or heat while coking or metallurgical coal is widely used as a fuel or in the production of iron ore. Although concerns have been raised regarding the contribution of coal to environmental pollution and greenhouse gas emissions, it remains one of the most traded energy commodities. Major coal-exporting countries include Australia and the United States, which rank first, followed by South Africa, Russia, and Colombia.

2.1.3 Iron ore

Except for coal, another significant mining raw material widely used and traded is the iron ore used for the extraction of metal. Iron Ore is a mineral extracted from the surface's ground and can be found in different forms and is considered to be one of the most abundant elements after oxygen and aluminum. Metals and steel are necessary for industrial activity and the infrastructure projects taking place, especially in economically developing countries. The mining of iron ore takes place mainly in the major extracting areas such as Australia at the area of Pilbara and in Brazil at Minas Gerais. Apart from Australia and Brazil, South Africa, Canada, and Sweden are some of the main exporting iron ore countries. On the import side China, Japan, and South Korea rank among the top importers.

2.1.4 Grains

Last but not least, some of the vital commodities are agricultural ones and include mainly raw materials such as grains, fertilizers, wheat, and soya beans. Grains in general are highly related to end consumers' diets and animals' feeding which explains the wide trading activity of the respective commodities. Fertilizers are a significant element related to the plant's viability and growth. Wheat is also one of the most important cereal crops used in food production and a basic factor in consumers' daily food consumption. Soya beans are also used as animal feed and are used for the

production of soy and soy oil consumed around the globe. The agricultural market is the third in terms of global production. The seasonality effect related to climate change and the harvesting activities highly affects the trading activity and the prices. Agricultural commodities are also affected by consumers' dietary trends and needs, related to a healthier nutritional diet. The basic exporters of agricultural commodities are Russia US, Brazil, Argentina, Australia, and France while the main importers are Asia with China ranking as the top importer due to its rising population and developing activities and Europe being the second largest consumer due to the strong economic position and the large domestic livestock industry.

2.2 Ports in the shipping industry

Waterways and maritime corridors play a pivotal role in alleviating heavy traffic on terrestrial routes and reducing logistics expenses facilitating the transportation of substantial cargo volumes. Navigable water bodies provide avenues for ships to conduct their logistics activities, a practice that has long demonstrated cost efficiency in international trade and long-haul transportation. For a long time, international trade and long-distance transportation have utilized the waterways, which have been a profitable and less expensive mode of cargo transportation. As the complexity of supply chain networks and economic expansion intensifies, inland transportation activities increase. Therefore, securing commercial facilities and safe waterways that increase the capacity of inland and coastal routes is an important task Thus, ensuring the security of commercial facilities and safeguarding navigable waterways to bolster the capacity of both inland and coastal routes emerges as an imperative undertaking (Lee, 2023). (2023, Eunsu Lee, Geographic Information Systems for Intermodal Transportation: Methods, Models, Applications).

2.2.1 Main ports and their significance

Ports serve as critical transportation hubs located on sea and river with waterways, equipped with intermodal facilities to facilitate vessels' safe arrival and departure. They function as distribution centers for industrial and agricultural products within the trading system. The production, operation, and development of ports yield direct economic outputs, contribute to national income, and employment, and foster financial growth within cities or countries. The expansion of infrastructure and construction projects, coupled with the development of modern industry and transportation, has

spurred the prosperity of existing port cities and the emergence of new ones (Haralambides, 2019).

Ports have evolved in key nodes in global supply chains, constituting essential infrastructure for regional economic expansion. Their development potential prospects are influenced by a blend of external and internal factors (Wang, 2016) .

Free trade and infrastructure advancements have heightened competition among neighboring and regional ports, including those of Northern Europe, Japan, and Southern China.

The competitive landscape of globalization has transformed the conservative structure of port competition. New developments have forced ports to compete more aggressively, necessitating them to adopt more assertive strategies and deploy more effective marketing approaches (Murati and Brokaj, 2014). As a vital tool for competition and marketing activities, a port's brand image is closely associated with marketing tools such as service quality, routing decisions, call frequencies, competitive pricing, managerial proficiency, IT integration, and infrastructure capabilities.

Notable among the congested ports in the Asia-Pacific region are Ningbo, Shanghai, Qingdao, Guangzhou, Tianjin, Dalian, Nanjing, Lianyungang, Suzhou, Tangshan, Wenzhou, Yantai, Rizhao, Xiamen, Quanzhou, and Zhanjiang in China.

Some of the ports that serve as crucial nodes in Europe's maritime trade network, facilitating the movement of goods between Europe and the rest of the world, include the Port of Rotterdam (Netherlands), Port of Antwerp (Belgium), Port of Hamburg (Germany), Port of Le Havre (France), Port of Felix Stowe (United Kingdom), Port of Barcelona (Spain), Port of Genoa (Italy). Each port has unique specialties and strengths, contributing significantly to regional and global trade flows.

3. The vessel

The term ship-vessel can be applied to navigable structure of woods, iron or steel, specially formed either for traversing seas, channel rivers etc. or to be moored in such waters for particulars services. A vessel, broadly defined, denotes any container or ship designed for holding substances, cargo, or passengers. The evolution of vessels reflects significant advancements in technology, materials, and engineering over millennia.

3.1 The Evolution of Vessels

The evolution of maritime vessels throughout history reflects significant advancements in transportation, commerce, and naval technology. This overview provides a formal exploration of early vessels, maritime developments in antiquity, and transformative innovations during the Industrial Revolution and beyond:

3.1.1 Early Vessels

- The Ancient Watercraft: The earliest vessels likely comprised simple rafts or dugout canoes crafted from logs, utilized by ancient civilizations for transportation and fishing purposes.
- The Ceramic Vessels: The emergence of pottery vessels around 10,000 BCE facilitated the storage and transport of food, liquids, and other commodities, marking a pivotal advancement in early maritime trade and navigation.

3.1.2 Maritime Vessels

- The Sailing Ships: Ancient civilizations, such as the Phoenicians and Greeks, developed sailing vessels for trade and exploration. Iconic examples include Phoenician merchant ships and Greek triremes employed for naval warfare and maritime commerce.

- The Medieval and Renaissance Ships: The Middle Ages witnessed significant advancements in shipbuilding techniques, resulting in the construction of larger and more seaworthy vessels like galleons and carracks. These ships played a crucial role in European exploration and trade during the Renaissance period.

3.1.3 Industrial Revolution and Beyond

- The Steamships: The 19th century marked the advent of steam-powered ships, powered by revolutionary steam engine technology. Steamships transformed oceanic transportation and commerce, facilitating faster and more reliable journeys across vast distances.

- The Modern Vessels: The 20th century ushered in a new era of naval innovation, introducing submarines, aircraft carriers, and specialized cargo vessels designed to meet the demands of modern warfare and global trade networks. These vessels represent cutting-edge engineering and technological prowess in maritime operations.

This formal narrative underscores the progressive evolution of maritime vessels from ancient watercraft and sailing ships to the sophisticated naval technologies of the modern era. Each era of maritime history reflects profound societal, economic, and technological influences that continue to shape the maritime industry's trajectory and global connectivity (Tupper, 2013).

3.2 Basic Vessel Types

The classification and selection of vessel types vary across different maritime markets, tailored to specific cargo transportation requirements and trade routes. Shipowners, strategically assess their needs, market conditions, and areas of expertise to decide between commissioning a new-build vessel through a shipyard order or acquiring a pre-owned, operational vessel.

3.2.1 The Container Ship

Container ships are specialized vessels designed for the carriage of various goods, which are packed in standardized containers, including consumer products, electronics, machinery, and commodities. Goods are usually packed into standardized containers such as 20-foot or 40-foot units, at specific ports equipped with the necessary infrastructure or at manufacturing facilities. While container ships primarily carry cargo in containers, some also carry bulk cargo like grains or minerals in bulk containers or break-bulk form (Han Slawik, 2020).

The process begins with the delivery of the containers to the port and where they are then stacked in the designated container yard. Subsequently, cranes are employed to load the container boxes onto the ship, with the ship's crew and stevedores (port workers) ensuring that they are stowed in precise configurations to optimize weight distribution and stability. Containers are stowed in designated bays on deck and within the cargo holds following a meticulously prepared stowage plan. A stowage plan is

carefully structured, aimed at preventing accidents, cargo loss, and potential risks to crew members and stevedores.

Unlike other vessels, container ships sail predetermined routes between ports and operate along fixed routes, often part of scheduled services operated by shipping lines. This predictable scheduling enables stakeholders to anticipate the precise arrival and departure times for loading and unloading operations. Upon reaching the destination port, containers are discharged using port cranes and subsequently transferred to trucks or trains for distribution to end consumers (Dong-Wook Song, 2012).

3.2.2 The Tanker Ship

Tanker vessels, also referred to as tank ships or oil tankers, represent a specialized class of vessels engineered for the transportation of liquid cargoes, including crude oil, petroleum products, chemicals, liquefied natural gas (LNG), and various bulk liquids essential for global energy and industrial supply chains. These ships play a pivotal role in facilitating the movement of oil and petroleum products from extraction sites to refineries and distribution hubs worldwide. They are purpose-built cargo ships designed to efficiently transport large volumes of liquid cargoes, featuring specialized tanks for secure storage and transit of diverse liquids, ranging from crude oil to chemical compounds, liquefied gases, and edible oils.

The history of tanker ship development traces back to the late 19th century, a pivotal era marked by the transition from wooden barrels to metal containers for transporting oil. The inaugural purpose-built oil tanker, the "Zoroaster," set sail in 1878, inaugurating the era of modern tanker shipping. Subsequent advancements in tanker construction during the early 20th century embraced steel hulls, fostering enhanced safety and durability for transporting volatile and combustible liquids over vast maritime distances. The evolution of tanker design continued with innovative features like double hulls to fortify safety measures, segregated ballast systems to mitigate cargo contamination risks, and sophisticated cargo handling equipment capable of managing diverse liquid cargoes efficiently. Tanker vessels can be categorized as follows (Huber, 2001):

- **Crude Oil Tankers:** Crude oil tankers are purpose-built vessels designed to transport unrefined crude oil from production sites, such as oil fields, to refineries for processing. These tankers play a critical role in the global energy

supply chain, ensuring the efficient delivery of crude oil to meet industrial and consumer demands. The classification of crude oil tankers is based on their size and capacity, categorizing them into:

- **Very Large Crude Carriers (VLCCs)**: Typically exceeding 200,000 deadweight tons (DWT), VLCCs are among the largest vessels dedicated to crude oil transportation.
- **Ultra Large Crude Carriers (ULCCs):** Exceeding 300,000 DWT, ULCCs represent the pinnacle of tanker size and capacity, capable of transporting massive volumes of crude oil over long distances.
- **VLCCs and ULCCs** are equipped with multiple segregated cargo tanks, usually arranged in longitudinal and transverse compartments to minimize free surface effects. These vessels are fitted with powerful cargo pumping systems capable of handling large volumes of crude oil. Submersible cargo pumps are commonly used for efficient loading and discharge operations. Crude oil carriers are equipped with inert gas systems to prevent the buildup of flammable gases and maintain an inert atmosphere in the cargo tanks for safety. Many modern VLCCs and ULCCs are built with double hulls to enhance structural integrity and reduce the risk of oil spills in case of collisions or groundings. Crude oil carriers adhere to strict environmental regulations, including ballast water management and oil pollution prevention measures.

- **Product Tankers:** Product tankers are specialized vessels crucial for transporting refined petroleum products, including gasoline, diesel, jet fuel, and various chemicals essential for industrial and consumer applications. These vessels are instrumental in the global distribution network of petroleum products, ensuring the timely delivery of fuels and chemicals to diverse markets. Product tankers are categorized based on their size and operational capabilities:
  - **Handysize**: Typically ranging up to 50,000 deadweight tons (DWT), Handysize tankers are versatile vessels used for transporting refined petroleum products or chemicals over shorter routes. Their compact size enables efficient navigation in smaller ports and waterways, enhancing accessibility to regional markets.

- **Panamax**: Ranging from 50,000 to 80,000 DWT, Panamax tankers are designed to maximize cargo capacity while conforming to the dimensional constraints of the Panama Canal locks. These tankers optimize efficiency by facilitating transit through the Panama Canal, enabling seamless transportation between Atlantic and Pacific markets.
- **Aframax**: With a capacity ranging between 80,000 and 120,000 DWT, Aframax tankers are versatile vessels employed for both crude oil and refined product transportation. Their intermediate size allows for flexible operations across diverse trade routes, including coastal and intercontinental voyages.
- **Suezmax:** Designed to the maximum size permissible for transit through the Suez Canal (typically around 150,000 DWT), Suezmax tankers are optimized for the dimensional limitations of the Suez Canal locks. These tankers excel in long-haul crude oil transportation, facilitating efficient trade between the Mediterranean and Asian markets.

- **Chemical Tankers:** Chemical tankers are outfitted with multiple segregated cargo tanks, enabling the simultaneous transportation of different chemical cargoes while preventing cross-contamination and ensuring cargo integrity. Advanced safety systems, including inert gas systems and vapor recovery units, are employed to mitigate the risks associated with transporting hazardous substances such as acids, alkalis, petrochemicals, liquefied gases, and other toxic compounds. Additionally, non-hazardous chemicals, such as vegetable oils, edible oils, wine, and food-grade liquids, are transported under controlled conditions to maintain product quality and safety. Chemical tankers adhere to stringent safety standards and regulations established by international governing bodies such as the International Maritime Organization (IMO) and classification societies. These regulations govern vessel construction, operational procedures, and emergency response protocols to ensure the highest level of safety and environmental stewardship. Tanker crews undergo specialized training in chemical handling, emergency response procedures, and cargo tank management to mitigate operational risks and safeguard against potential hazards associated with chemical transportation.

The size and capacity of chemical tankers vary according to their intended cargo and operational requirements, spanning a broad spectrum of dimensions:

- **Coastal Tankers**: Compact vessels with capacities under 10,000 deadweight tons (DWT), tailored for short-haul coastal operations and regional distribution of chemical cargoes.
- **Deep-Sea Vessels:** Larger chemical tankers exceeding 50,000 DWT, deployed for long-haul voyages across international waters to meet global demand for chemical products.

- **Liquefied Gas Carriers:** LNG (Liquefied Natural Gas) and LPG (Liquefied Petroleum Gas) carriers represent a specialized fleet of vessels meticulously engineered for the transportation of natural gas in its liquefied state. These vessels serve as vital conduits in the global energy sector, facilitating the safe and efficient movement of natural gas from production sites to consumption markets across the globe.

  LNG carriers encompass a diverse range of sizes, from small-scale LNG bunkering vessels with capacities under 10,000 cubic meters to large-scale LNG carriers capable of transporting up to 266,000 cubic meters of liquefied natural gas. These carriers are instrumental in bridging supply-demand gaps and supporting the development of liquefied natural gas infrastructure worldwide. LNG carriers are characterized by their substantial dimensions, tailored to meet the operational requirements of LNG terminals and ports.The fundamental types of LNG carriers include:

  - **Membrane-Type LNG Carriers**: These vessels employ specialized membrane cargo containment systems crafted from advanced materials capable of withstanding extreme cryogenic temperatures and pressures. Membrane tanks ensure the safe transportation of LNG under challenging environmental conditions.
  - **Moss-Type LNG Carriers:** Featuring spherical or cylindrical cargo tanks enveloped by insulation layers, Moss-type LNG carriers preserve liquefied natural gas integrity during transit. Reinforced construction materials enhance structural robustness and safety, maintaining cargo stability and containment.

- **LPG (Liquefied Petroleum Gas)** carriers represent a diverse fleet of vessels meticulously engineered for the transportation of liquefied petroleum gas in its various forms. These vessels are instrumental in supporting the global energy sector by facilitating the safe and efficient movement of LPG from production sites to distribution terminals and end-user markets. The primary types of LPG carriers include:
    - **Fully Pressurized LPG Carriers**: Engineered to transport LPG in a pressurized state at ambient temperatures, fully pressurized vessels offer versatility and can accommodate a range of LPG grades and compositions.
    - **Fully Refrigerated LPG Carriers**: These vessels transport LPG under refrigeration to maintain the cargo in a liquid state at atmospheric pressure. Equipped with insulated cargo tanks and reliquefication systems, refrigerated LPG carriers minimize cargo loss and ensure optimal product integrity during transit.

    LNG and LPG carriers adhere rigorously to stringent safety regulations prescribed by international bodies such as the International Maritime Organization (IMO) and reputable classification societies. These safety protocols encompass comprehensive crew training in LNG and LPG handling procedures, emergency response protocols, and fire prevention strategies.

    Furthermore, LNG and LPG carriers are equipped with redundant safety systems, including double hulls, gas detection sensors, and emergency shutdown mechanisms. These measures are essential to mitigate operational risks and ensure the safety of personnel and cargo during transit. LNG and LPG carriers play indispensable roles in the global energy supply chain by facilitating the secure and efficient transportation of natural gas products across oceans and waterways. They are engineered and operated with a paramount emphasis on safety, environmental stewardship, and adherence to regulatory mandates, ensuring the integrity of the cargo and minimizing risks associated with handling liquefied gases at sea (Sullivan, 2022).

Tanker vessels are critical components of the global energy and chemical industries, facilitating the efficient and safe transport of liquid cargoes across oceans and waterways. Advances in tanker design, safety standards, and environmental regulations

continue to shape the evolution of tanker shipping, ensuring the sustainability and reliability of liquid cargo transportation.

3.2.3 The Bulk Carriers

Dry cargo vessels, also known as bulk carriers, are ships designed for transporting unpackaged cargo such as grains, coal, iron ore, cement, and similar dry commodities in large quantities. These vessels are specifically designed to efficiently handle and transport bulk cargo over long distances across oceans and waterways.

Bulk carriers are the most common type of dry cargo vessel. They are designed with large holds to carry bulk cargo, either in solid form (e.g., ore, grains) or in powder form (e.g., cement, sugar). Historically, cargo was transported by sailing ships and early steamships, mainly for regional and coastal trade. The 20th century saw the rise of specialized bulk carriers designed for efficient transport of bulk commodities. This led to the development of different types of bulk carriers optimized for specific trade routes and cargo types. Modern bulk carriers have become larger and more efficient, incorporating innovations such as double hulls, specialized cargo handling equipment, and fuel-efficient propulsion systems. Bulk carriers can be categorized based on their size and capacity:

- **Handy size:** Typically, smaller vessels suitable for serving smaller ports with restrictions on draft and size.

  Ranges from around 15,000 DWT to 35,000 DWT

  Number of Holds: Typically, 4 to 7 cargo holds.

  Number of Hatches: Each cargo hold usually has its own hatch cover.

  Particulars: Smaller size and draft, making them suitable for serving smaller ports with restrictions.

  Cargo handling equipment may include cranes or derricks for loading and discharging.

- **Handymax:** Slightly larger than Handysize vessels, capable of carrying more cargo while still accessing a wide range of ports.

  Ranges from approximately 35,000 DWT to 60,000 DWT

  Number of Holds: Typically, 5 to 9 cargo holds.

  Number of Hatches: Each cargo hold is covered by separate hatch covers.

Particulars: Larger capacity than Handysize vessels, suitable for a wider range of cargo types and trade routes.

May have more advanced cargo handling equipment such as grabs or conveyor systems.

- **Panamax:** Sized to fit through the Panama Canal's locks, with restrictions on length, width, and draft.

  Ranges around 60,000 DWT to 80,000 DWT

  Number of Holds: Typically, 5 to 9 cargo holds.

  Number of Hatches: Each cargo hold is covered by separate hatch covers.

  Particulars: Designed to fit the dimensions of the Panama Canal locks (length, beam, and draft restrictions).

  Advanced cargo handling equipment to maximize efficiency in canal transits and port operations.

- **Capesize:** Large vessels that are too big to transit the Panama or Suez Canal, often used for long-haul routes.

  Ranges from about 100,000 DWT to over 200,000 DWT

  Number of Holds: Typically, 7 to 9 cargo holds.

  Number of Hatches: Each cargo hold is covered by separate hatch covers.

  Particulars: Largest bulk carriers, often used for long-haul routes and major bulk commodity trades. Can accommodate larger cargo volumes and heavier individual cargo parcels.

  Advanced cargo handling equipment, including cranes or conveyor systems, to efficiently load and discharge cargo.

  In addition to cargo holds and hatches, bulk carriers may also be equipped with other specialized features such as ballast systems, cargo handling cranes, ventilation systems, and safety equipment tailored to the specific needs of bulk cargo transportation. The design and layout of bulk carriers aim to optimize cargo handling efficiency, minimize cargo damage, and ensure safe operations throughout the vessel's service life. Specific details about individual vessels can vary based on the shipbuilder, owner/operator preferences, and evolving industry standards (Isbester, 1993).

3.2.4 The Passenger Ships

Passenger ships, also referred to as passenger vessels or cruise ships, are vessels dedicated to the transportation of passengers along with their belongings, including luggage and personal items. These ships have undergone significant evolution in design, size, amenities, and safety features throughout history.

Traditionally, passenger ships served as means of transportation across seas and oceans, ranging from smaller vessels transporting passengers and cargo regionally to larger ocean liners facilitating long-distance travel. However, in the mid-20th century, passenger ships transitioned into specialized cruise ships focused on providing leisure and vacation experiences (Maxtone-Graham, 2020). This shift towards cruise tourism spurred innovations in ship design, onboard amenities, and entertainment offerings.

Modern passenger vessels, particularly cruise ships, are meticulously designed to prioritize comfort, luxury, and entertainment for guests. They are equipped with multiple decks featuring a diverse array of facilities such as restaurants, bars, theaters, spas, pools, and various recreational activities (Smith, 2011).

The length of passenger ships varies significantly, ranging from small coastal ferries measuring approximately 50 meters (164 feet) to expansive cruise ships exceeding 300 meters (984 feet) in length. Longer vessels can accommodate larger passenger capacities and offer expanded amenities and entertainment options. Passenger capacity plays a pivotal role in ship design, influencing the layout, amenities, and safety features implemented onboard (Dawson, 2000).

Overall, the evolution of passenger ships underscores a profound commitment to enhancing the travel experience for passengers while prioritizing safety and comfort in maritime transportation.

3.2.5 The Ro-Ro Ship (Roll-on/Roll-off)

The Roll-on/Roll-off (Ro-Ro) ship is a specialized vessel designed for the transportation of vehicles, including cars, trucks, and trailers, which can be driven on and off the vessel under their own power. The concept of Ro-Ro shipping emerged in the mid-20th century as a more efficient alternative to traditional cargo handling methods involving cranes or ramps.

Ro-Ro ships provide a cost-effective and time-efficient solution for transporting vehicles, significantly reducing handling time and labor costs associated with loading and unloading operations. They play a crucial role in intermodal transport by seamlessly

integrating maritime shipping with road and rail networks. Ro-Ro terminals are strategically positioned near major population centers and industrial hubs to optimize supply chain logistics.

Initially employed for short sea routes, Ro-Ro technology has evolved over time, giving rise to larger and more specialized vessels capable of accommodating a diverse range of wheeled and containerized cargo. Global Ro-Ro operations span both domestic and international trade routes, facilitating the efficient movement of goods.

The dimensions of Ro-Ro ships vary widely based on their capacity and intended use. Small Ro-Ro ferries may measure less than 100 meters (328 feet) in length, while larger vessels utilized for international trade can exceed 200 meters (656 feet).

Overall, Ro-Ro ships have become integral components of modern logistics and transportation systems, offering flexibility, efficiency, and reliability for the conveyance of wheeled cargo across domestic and international trade routes. Their ongoing evolution involves advancements in technology, safety features, and environmental sustainability to meet the evolving demands of global commerce.

3.2.6 Tugboats

Tugboats, also referred to as tugs or towboats, represent specialized vessels designed specifically for the towing and maneuvering of other vessels and maritime structures, including barges, ships, floating docks, and oil rigs. They fulfill essential roles in harbor operations, ship assistance, salvage undertakings, and maritime construction endeavors. Tugboats are characterized by their compact yet robust construction, notable maneuverability, and robust towing capabilities.

The historical lineage of tugboats spans centuries, evolving from smaller craft propelled by oars or sails to steam-powered and subsequently diesel-powered tugs during the 19th and 20th centuries. The adoption of more potent engines and enhanced towing equipment facilitated the handling of larger vessels and heavier loads, bolstering the efficacy of tugboat operations.

Tugboats exhibit varying dimensions contingent upon their designated purpose and towing capacity. Harbor tugs, tailored for localized operations, typically measure around 20 meters (66 feet) in length, while ocean-going tugs intended for broader maritime duties can exceed 40 meters (131 feet). Equipped with formidable winches, towing hooks, and robust towing lines, these vessels are adept at managing substantial loads and executing secure towing maneuvers.

Modern tugboats incorporate cutting-edge propulsion technologies such as azimuth thrusters or Voith Schneider propellers to augment maneuverability and dynamic positioning capabilities. Their versatility renders them indispensable assets within the maritime industry, fulfilling critical functions in ship handling, towage operations, and emergency response scenarios.

The ongoing evolution of tugboats underscores a commitment to technological advancement and sustainability initiatives aimed at enhancing the efficiency and reliability of marine operations on a global scale. These vessels remain pivotal in facilitating safe and efficient maritime activities, poised to adapt and innovate in alignment with emerging industry demands and environmental considerations.

4. The Shipping Cycle

The shipping cycle is a fundamental concept in the maritime industry, describing the fluctuations in shipping markets over time. Cycles do not refer only to the shipping industry and they occur in other industries as well. A cycle is characterized by distinct phases that reflect changes in supply and demand for shipping services affecting stakeholders' decisions and moves. The primary phases of the shipping cycle are though, recovery, peak and collapse. Each phase affects different stakeholders in the shipping industry and influences market conditions.

4.1 Phases of the Shipping Cycle

The shipping cycle can be redefined using the phases of "Through," "Recovery," "Peak," and "Collapse" (Stopford, 2009). Here's an analysis of each phase with the reactions of shipowners, charterers, and other stakeholders:

4.1.1 Through (Recession)

During this phase, the demand for shipping services declines. This decline stems from the fact that the market has reached its peak concerning the number of operational fleets, resulting in an overcapacity of vessels. The surplus of vessels leads to falling freight rates, which may prompt decisions to lay up or scrap vessels. Profitability for vessel owners is reduced, as freight prices fall to the level of operational costs. Financial

pressures force vessel owners to sell their vessels below book value to raise cash. This phase is characterized by an economic slowdown and reduced trade volumes.

To avoid laying up or scrapping vessels, shipowners compete intensely to at least cover their operational costs. Many owners struggle with loan repayments due to insufficient cash flows from vessel operations. Financial distress delays new investments and halts new ship orders, as the market has already reached its maximum vessel capacity.

Conversely, charterers benefit from lower freight rates due to the abundance of vessels available to meet their transportation needs. However, the market conditions may lead to reduced demand for their own products. In response, charterers optimize their transportation costs and renegotiate existing contracts to mitigate financial risk.

Shipyards, during this phase, experience a significant decline in new orders because the market has reached its maximum vessel capacity. As shipbuilders face reduced profitability and fewer contracts, they may be forced to reduce their workforce or delay projects due to cash flow shortages. Shipyards will take corrective actions, focusing on maintaining existing contracts or reducing operational costs.

Banks and financial institutions, recognizing the adverse market conditions, tighten their lending criteria to manage the increased risk of loan defaults. Their primary focus shifts to restructuring existing debts rather than issuing new loans.

Investors and stakeholders become cautious and selective about investments in the shipping industry. Those with the capacity seek distressed assets or opportunities for consolidation (Stopford, 2009), (Grammenos, 2010).

4.1.2 Recovery

During the recovery phase, the shipping industry experiences a gradual improvement in demand for shipping services, leading to stabilizing and eventually increasing freight rates, and improved ship utilization. The confidence starts to grow and market conditions are characterized by economic recovery, increased trade volumes, and an emerging balance between supply and demand (Lund, 2015).

Shipowners see improved profitability and begin to resume investments since liquidity is gradually improving. They conduct maintenance, consider ordering new ships cautiously, and bring laid-up vessels back into operation. Charterers face increasing freight rates but benefit from improved economic conditions. They may secure long-term contracts to lock in lower rates before further increases. Shipbuilders witness a

modest increase in new orders and cautiously ramp up production, planning for future workforce and capacity increases (Stopford, 2009).

Financiers gradually increase lending activity but remain cautious, focusing on financing projects with strong fundamentals. They offer refinancing options to struggling companies showing signs of recovery. Investors start to see opportunities for growth and profitability in the shipping sector, investing in companies with strong recovery potential and looking for merger and acquisition opportunities (Grammenos, 2010).

4.1.3 Peak

During the peak phase, the shipping industry experiences high demand for shipping services, leading to increased freight rates and full utilization of shipping capacity, resulting in high profitability for shipowners. Market conditions are characterized by strong economic growth, high trade volumes, and potential capacity shortages.

Shipowners maximize profits and invest heavily in new ships. They delay scrapping older vessels to maintain capacity and expand operations and fleet sizes. High earnings generate increased liquidity leading to over-trading as second-hand prices move way above their replacement cost and owners invest in buying vessels without even proceeding with inspection. Charterers face higher freight rates, leading to increased transportation costs and may struggle to secure shipping capacity during peak times. They consider entering long-term contracts to mitigate cost increases. Shipbuilders experience a surge in orders for new vessels, increase production capacity, and hire more workers. They focus on meeting high demand and delivering orders on time (Grammenos, 2010).

Financiers increase lending activity for new ship purchases and expansions, offering favorable financing terms due to strong market conditions. They invest in shipping companies with strong growth prospects and are keen to finance against strong asset value. Investors actively invest in shipping companies to capitalize on high returns, look for high-growth opportunities in the sector, and monitor for signs of market overheating and potential overcapacity.

4.1.4 Collapse (Crisis)

During the collapse phase, supply overtakes demand. The shipping industry experiences an oversupply of ships, leading to a sharp decline in freight rates, reduced

profitability, and financial distress for shipowners. The demand for shipping services declines amid an economic downturn, reduced trade volumes, and significant overcapacity in the shipping fleet.

Shipowners face severe financial difficulties and may go bankrupt. They lay up ships, delay or cancel new investments, and focus on restructuring and cost reduction. Charterers benefit from lower freight rates, reducing transportation costs, but may face challenges due to the economic downturn affecting their own demand. They renegotiate contracts to take advantage of lower rates (Stopford, 2009).

Shipbuilders experience a steep decline in new orders and may face financial difficulties, leading to workforce reductions. Shipyards at that stage focus on managing existing projects and reducing costs. Financiers deal with increased defaults on loans, tighten credit terms, and reduce new lending activity. They focus on managing existing exposures and restructuring troubled loans.

Investors become very cautious or withdraw from the shipping sector, looking for distressed assets or opportunities for consolidation at low prices. They assess market conditions carefully before making new investments.

4.2 The Shipbuilding Activity

The shipbuilding industry is highly linked to the stages of the shipping market cycle. Each phase—Through, Recovery, Peak, and Collapse—has distinct effects on the shipbuilding activity, influencing how shipbuilders react to changing market conditions (Lund, 2015).

During the Through phase, the shipbuilding industry experiences a significant decline in new orders due to reduced demand for shipping services. The oversupply in the existing fleet leads to a reluctance to invest in new ships, causing financial strain and operational challenges for shipyards. In response, shipbuilders may be forced to reduce their workforce, both ashore and on board, due to decreased demand. Their focus shifts to managing operational costs and maintaining cash flow. Existing projects may be delayed or postponed due to financial constraints, and smaller shipyards may seek mergers or alliances to survive the downturn.

In the Recovery phase, there is a gradual increase in new orders as market conditions improve. Improved ship utilization and the stabilization of freight rates stimulate demand for new vessels, and shipyards begin to see a resurgence in activity.

Shipbuilders cautiously maximize production to meet increasing demand and begin planning for future workforce and capacity increases to accommodate anticipated growth. Additionally, they focus on maintaining and upgrading facilities to enhance efficiency and capacity.

During the Peak phase, the shipbuilding industry experiences a surge in new orders due to high demand for shipping services and increased profitability for shipowners. Full utilization of shipping capacity and potential capacity shortages drive investment in new ships, resulting in high levels of activity and profitability for shipyards. In reaction, shipyards increase production capacity and hire additional workers to meet high demand. They focus on meeting delivery schedules and maintaining high standards to capitalize on favorable market conditions. Moreover, shipbuilders invest heavily in new technologies and facilities to enhance production capabilities.

The Collapse phase brings a sharp decline in new orders as an oversupply of ships leads to reduced demand. Financial distress for shipowners results in cancellations or delays of existing orders, and the economic downturn coupled with significant overcapacity in the fleet causes severe challenges for shipyards. To survive the downturn, shipbuilders implement strict cost-cutting measures and prioritize the completion of existing projects while minimizing new ones. Some shipyards may diversify into other sectors or services to mitigate the impact of reduced shipbuilding demand, while others seek strategic alliances or partnerships to share risks and resources (Stopford, 2009), (Grammenos, 2010).

4.2.1 Shipowners' Decisions for a New Build New Ships

The decision to build a new ship is a significant strategic choice for shipowners, influenced by various market, financial, and operational factors. Shipowners must assess current and projected market conditions, the state of the shipping cycle, and the specific needs of their fleet. The common motivation behind ordering a new build often includes the desire to modernize the fleet, meet new regulatory standards, or capitalize on favorable market conditions. Several critical factors influence the decision to invest in a new vessel. Shipowners' decisions to invest in new vessels are influenced by a variety of factors related to market conditions, technological advancements, financial considerations, and operational needs. High and stable freight rates may justify the investment in new vessels, as the anticipated revenue can offset the significant initial outlay. Projections of increased trade volumes and economic growth can drive the

decision to expand the fleet with new builds. Additionally, new builds often incorporate the latest advancements in fuel-efficient technologies, which reduce operational costs and environmental impact. New regulations regarding emissions and safety standards may necessitate the construction of new vessels to ensure compliance (Stopford, 2009). From a financial perspective, access to favorable financing terms and low interest rates can make the investment in new builds more attractive. On the contrary, the overall cost of constructing a new vessel, including labor and materials, directly impacts the decision of a shipowner. Operational needs also play a critical role. To stay competitive, shipowners may need to replace aging vessels with more advanced and efficient new builds (The Baltic Exchange,Carly Fields & Lara Shingles, 2018). Furthermore, increased demand for specific types of vessels may prompt the need for new constructions to meet market requirements. These factors collectively influence the strategic choices shipowners make regarding fleet expansion and modernization (Storch, 1995).

4.2.2 Considerations Before Investing in a New Vessel

Before committing to a new build contract, shipowners undertake a comprehensive evaluation process that includes:

- **Cost-Benefit Analysis (CBA)**: Process for assessing the long-term benefits of a new build against its projected costs, including construction, maintenance, and operational expenses. A method used to mitigate the risk of an investment decision by determining the costs and the benefits (Harvard Business School Online,Tim Stobierski, 2019).
- **Return on Investment (ROI)**: A financial ratio that estimates the potential returns and payback period based on projected earnings from the new vessel. The ROI ratio is calculated by subtracting the initial cost of the investment from its final value, then dividing this new number by the cost of the investment, and finally, multiplying it by 100. The higher the ratio, the greater the benefit earned. There are two methods of calculation (Corporate Finance Institute,Tim Vipond, n.d.):

Method1

$$\textbf{ROI} = \frac{\textbf{F}\text{inal}\textbf{V}\text{alue of}\textbf{I}\text{nvestmen}\textbf{t-I}\text{nitial}\textbf{V}\text{alue of}\textbf{I}\text{nvestment}}{\textbf{Cost of Investment}} \times \textbf{100\%}$$

Method2

$$\textbf{ROI} = \frac{\textbf{Net Return on Investment}}{\textbf{Cost of Investment}} \times \textbf{100\%}$$

- **Market Research**: Conducting thorough market analysis to predict future demand and freight rates by gathering and interpreting information usually provided by brokers or companies specialized in market research and data provision, for example Clarkson's Research (The University of North Carolina, 2024).
- **Regulatory Environment**: Ensuring the new vessel will comply with current and upcoming regulations especially those implemented on an international level by organizations such as the IMO (International Maritime Organization) (Science Dierct - Qiumeng Yuan, Shengzheng Wang, Jing Peng, 2023) , (DNV, 2024).
- **Technological Integration**: Evaluating the latest technological advancements and their potential impact on operational efficiency and cost savings, taking into account the environmental protection requirements such as the Net Zero target and the sustainable conduct of operations (Theo Notteboom, 2022).

4.2.3 Advantages and Disadvantages of New Build vs. Second-Hand Vessels

There are various advantages and disadvantages to be taken into account before the decision making on an investment related to a new build project. Some of the most common pros and cons when comparing the investment on a build with an investment in a second-hand vessel are as follows:

Advantages of New Builds

- **Technological Advantage**: New builds often feature the latest technology, resulting in better fuel efficiency, lower emissions and cost-effective operations.

- **Regulatory Compliance**: Newly constructed ships are designed to meet the latest regulatory standards, reducing the risk of non-compliance penalties and the cost of modifications and adjustments of vessels, to upgrade ship facilities.
- **Operational Efficiency**: Newer vessels typically offer improved performance and lower maintenance costs, complying also with the regulations issued by the International Maritime Organization such as the carbon intensity indicator (CII) for the reduction of carbon emissions in the shipping industry.
- **Customization**: Shipowners can customize new builds to meet their specific operational needs and preferences, in accordance to the newest designs offered by the shipyards (Stopford, 2009).

Disadvantages of New Builds

- **Higher Initial Costs**: The construction of new vessels requires a significant capital investment compared to purchasing second-hand ships. Capital, in most of the cases is acquired by a specific loan linked to the new build vessel and having the vessel as a mortgage in case of any default.
- **Long Lead Times**: The shipbuilding process can be lengthy, leading to delays in fleet expansion. The delivery of vessel can take more than two years and many shipowners proceed with new orders simultaneously when projections for a profitable market are high.
- **Market Risk**: Prolonged construction periods may expose shipowners to market volatility, affecting the projected profitability taking into considerations the shipping cycle phases and other unforeseen events (Stopford, 2009).

Advantages of Second-Hand Vessels

- **Lower Capital Investment**: Purchasing second-hand vessels typically requires less initial capital outlay.
- **Immediate Availability**: Second-hand ships are available for immediate deployment, allowing for quick fleet expansion since vessels are already operating in the market.

- **Market Flexibility**: The ability to quickly adapt to changing market conditions by acquiring or selling second-hand vessels to either take advantage of a rising market or to mitigate the risks from a declining market (Stopford, 2009), (Science Direct-Lixian Fan,Bingmei Gu,Jingbo Yin, 2021).

Disadvantages of Second-Hand Vessels

- **Higher Operating Costs**: Older vessels may be less fuel-efficient and require more maintenance and repairs costs, leading to higher operational expenses.
- **Regulatory Compliance Issues**: Second-hand ships may not meet the latest regulatory standards, necessitating costly retrofits and upgrades to meet the regulators requirements.
- **Shorter Lifespan**: The remaining useful life of second-hand vessels may be limited compared to new builds, affecting long-term profitability, considering that a vessel's useful life is about 25 years (Stopford, 2009), (Science Direct-Lixian Fan,Bingmei Gu,Jingbo Yin, 2021)

5. The Shipyards

A shipyard is a facility dedicated to the construction, maintenance, and repair of ships which can range in size, designed for global navigation. Typically, a shipyard is strategically located along a major inland river, harbor, or coastline, and some historic shipyards have been operational in the same location for centuries. Numerous professionals, including naval architects, engineers, electricians, and various other skilled tradespeople, work collaboratively in a shipyard to contribute to the construction of a vessel.

The shipbuilding industry has evolved significantly due to advancements in material types, navigation systems, and communication technologies. Key milestones in the development of modern ships include the use of iron in shipbuilding in 1777, the adoption of steam engines for ships in 1821, and the incorporation of steel in shipbuilding in 1862. These innovations led to the rapid expansion of global trade and played a crucial role in shaping the contemporary world order. This progression

accelerated with the geographical discoveries beginning in the early 14th century, predominantly led by nations advanced in maritime capabilities and shipbuilding.

Over time, the shipbuilding industry transitioned from the developed European countries, which had achieved economic prosperity by the early 1970s, to East Asian countries. Nations that lead global trade and dominate the maritime fleet are concurrently engaged in significant endeavors within the shipbuilding industry. European countries shifted from constructing low-income ship types such as tankers and bulk carriers to high-income passenger ships and warships by 1987. By the 2000s, the high demand for shipbuilding set the country of South Korea to the forefront of the industry. The Republic of China had also expanded its capacity through substantial investments in shipbuilding, securing the second position after South Korea in terms of tonnage (Todd, 2019), (Stopford, 2009).

5.1 Key players in the shipbuilding sector

The global shipbuilding industry is dominated by several key players known for their excellence in vessels construction, engineering, innovation, and reliability. Among the most reputable shipyards are Hyundai Heavy Industries in South Korea, Imabari Shipbuilding in Japan, and Fincantieri in Italy. Hyundai Heavy Industries, located in Ulsan, South Korea, is known for its large-scale production capabilities and advanced technology, consistently leading global shipbuilding rankings (Hyundai Heavy Industries, 2023). Imabari Shipbuilding, based in Ehime, Japan, is known for its meticulous craftsmanship and focus on eco-friendly ships, a significant environmental priority those days (Imabari Shipbuilding Co., Ltd., 2023). Fincantieri, is a shipyard located in Trieste, Italy, which stands out for its specialization in cruise ships and naval vessels, leveraging its long history and diversified expertise (Fincantieri, 2023). Customers choose these shipyards due to their proven track record of delivering high-quality, innovative ships on time and within budget, their adherence to stringent safety and environmental standards, and their excellent after-sales support services. These attributes ensure that shipowners receive vessels that meet the highest industry standards, contributing to the shipyards' esteemed reputations (Todd, 2019).

As of the latest data, these countries continue to lead the market due to their advanced shipbuilding facilities, technological advancement and large-scale production capabilities (UN Trade and Development, 2023).

- **South Korea**: South Korea holds the largest market share in the global shipbuilding industry. Companies like Hyundai Heavy Industries, Samsung Heavy Industries, and Daewoo Shipbuilding & Marine Engineering contribute significantly to this dominance. South Korea's market share is approximately 35-40% of the global shipbuilding orders (Organisation for Economic Co-operation and Development, 2022).
- **China**: China is ranking second, with a rapidly growing shipbuilding industry. The Chinese government's significant investments in shipbuilding infrastructure and technology have driven the country to the forefront of the shipbuilding industry. China's market share is around 30-35% on a global scale (Clarksons,Stephen Gordon, 2023), (Organisation for Economic Co-operation and Development, 2022).
- **Japan**: Japan, historically a leader in shipbuilding, maintains a strong position in the market. Major players include Imabari Shipbuilding and Japan Marine United. Japan's market share is about 15-20% of the global orderbook (Organisation for Economic Co-operation and Development, 2022).
- **Europe**: European countries, particularly those with a focus on specialized and high-value vessels such as cruise ships and naval vessels, also have a notable presence. Italy's Fincantieri, Germany's Meyer Werft, and France's Chantiers de l'Atlantique are key players. Europe 's Market is around 5-10% (Organisation for Economic Co-operation and Development, 2022).
- **Other Countries**: Other nations, including the United States, Vietnam, and the Philippines, have smaller but significant shipbuilding industries, focusing on niche markets and specific vessel types. These countries collectively hold about 5-10% of the market share (Ibp, 2014), (Halil Ibrahim Caner and Cevdet Coşkun Aydin, 2021), (Organisation for Economic Co-operation and Development, 2022).

6. The Vessel Construction

When comparing two shipyards with equivalent technological quality, the final price becomes the basic factor affecting clients' decisions. The cost structure for investing in a new ship differs significantly from that of secondhand ships, along with the amount of capital required. Initially, the cost equates the contract price which has been agreed with the shipyard and the vessel's potential owner. This cost beard by the shipowner, includes the borrowing, the hedging and the repositioning costs:

- The cost of any option purchased to secure a future slot in the yard.
- The installment payments to the yard during the building phases, that may include incremental or variation costs associated with design changes, price escalations during the construction
- The borrowing costs eligible for capitalization and costs associated with hedging future stage payments
- Costs such as inspection and certification costs
- Other repositioning costs, including first fill of lube-oil and bunker fuel

6.1 Borrowing and hedging costs beard by the owner

Borrowing costs that are directly associated with the construction of the new build and are capitalized, as it generally takes a sufficient period of time to build a new vessel. Borrowing costs usually include certain finance charges and foreign exchange differences that are regarded as an adjustment to interest costs. They may also include payments and accruals made under interest rate swaps used for hedging of eligible borrowing costs. Moreover, some vessel construction contracts may take place in currencies other than the functional currency of the company, usually United States Dollars. In order to mitigate its exposure to fluctuations in exchange rates a company may use hedging as a measure (KPMG, 2013).

6.1.1 Repositioning costs beard by the owner

In a general manner, any pre-operating costs are not eligible for capitalization, unless these costs are imperative to bring the asset to its fully working condition. Therefore, costs incurred up to the moment when the vessel is capable of operating in the intended

manner (including moving it to a required location) do meet the definition of an eligible cost. Many companies that wish to capitalize costs, consider repositioning costs from the yard to the nearest major port, rather than the actual costs incurred in moving the vessel to a port of choice (or port determined under a charter party contract). In some cases, a vessel may also generate an operating loss in its first days at sea, as it moves from the yard to the commencement of its first laden voyage. The operating loss is expensed as incurred (KPMG, 2013).

6.2 The Cost Components for a new build

The cost components involved in building a new ship include both tangible and non-tangible elements. Tangible elements include the hull, hull equipment, galley and mess room equipment, installation of machinery, motor aids and pumps, external tanks, equipment, moorings and flaps, safety equipment, other equipment, deck machinery, construction services, and third-party costs. The non-tangible elements comprise costs such as port costs, classification society costs, exchange rates resulting from different currencies, inflation, employees' wages, planning and development time, design drawing, design image authentication time, design image attestation time, third-party design drawings among others. Noteworthy elements that significantly impact cost estimations include exchange rates, inflation, and the regional minimum wage. The estimated price of new ship construction is derived from the accumulated experience of various shipyards over several decades, using the gross tonnage (GT) per USD as a standard unit of measurement.

From a shipyard's point of view, the cost structure for constructing a new ship comprises five fundamental components: the hull construction, the deck machinery, the ship propulsion system, the auxiliary machinery systems, and the associated financing structures. Each of these elements are taken into account and are critically assessed to determine the overall cost (Horngren, 2018). The approach to estimating these costs typically involves calculating the gross tonnage per USD, providing a comprehensive evaluation of the financial requirements for the construction of a new vessel. The construction of a vessel is divided in several critical phases, each one requiring meticulous planning, coordination, and execution. The phases can be structured as follows:

Design and Planning: This primarily phase includes the conceptual design, the detailed design, and the preparation of technical specifications already agreed between the potential shipowner and the shipyard. Naval architects and marine engineers work collaboratively to ensure that the vessel meets the regulatory design and technical standards together with the client requirements.

Procurement of Materials: This phase involves sourcing and purchasing of materials and spare parts, including steel, equipment, and other essential components. Contracts and prices are negotiated with suppliers to secure high-quality materials at competitive prices.

Construction of the vessel's Hull: Being the primary structure of the vessel, the hull, is assembled from prefabricated steel sections. This phase includes the cutting, the welding, and the joining of the steel plates and sections to form the ship's framework.

Outfitting: The outfitting includes the installation of various equipment and systems, such as engines, generators, navigation systems, and accommodation facilities. This stage is crucial for ensuring that all components are integrated accurately and functioning rightly.

Painting and Coating: Protective coatings such as acrylic, alkyd, epoxy, polyurethane, silicone coatings, are applied to the vessel's exterior and interior surfaces to prevent any corrosion and ensure vessel's longevity. This phase is critical for maintaining the structural integrity of the ship. providing good adhesion, high water and vapor resistance as well as high resistance to abrasion, impact and chemical attack.

Launch and Trials: Once the construction and the outfitting are completed, the vessel is launched and undergoes sea trials to ensure the vessel's performance level, the proper operation of the main and auxiliary machinery and the overall seaworthiness and cargo worthiness. These trials test the ship's performance and safety under operational conditions.

Delivery and Commissioning: After the successful trials, the vessel is ready to be delivered to the owner. The final phase includes manning of the vessels and training of the crew, final inspections, and obtaining the necessary certifications (Drury, 2015).

6.3 Shipyard Cost Considerations

When a shipyard is budgeting for a vessel construction, the following costs must be meticulously accounted for:

Steel and Other Materials: Given that steel is a major component, fluctuations in steel prices have a significant impact on the overall costs. Additional materials such as aluminum, composites, and specialized alloys must also be considered.

Machinery and Equipment: This includes main engines, auxiliary engines, propulsion systems, and other critical machinery. The choice of technology e.g., conventional vs. advanced propulsion systems also affects costs.

Labor Hours: Comprises the total man-hours required for the construction of a new build, including skilled labor for welding, electrical work, and installation of systems. Efficient labor management can help control costs.

Outfitting and Finishing: The cost of outfitting the vessel with necessary systems and facilities. This phase can be costly due to the complexity of integrating various components.

Testing and Trials: Costs associated with conducting sea trials to ensure vessel's performance, including fuel, crew wages, and potential modifications required based on trial outcomes.

Contingency Funds: A contingency budget to cover any unexpected expenses or delays. This is essential for mitigating financial risks during the construction of a new build.

6.3.1 Price Formation Elements

The price of constructing a vessel is determined by several elements/ However, it cannot only be based on predetermined market prices of the components but is very likely to be affected by inflation percentages that including:

Material Costs: The cost of raw materials, particularly steel, which constitutes a significant portion of the ship's structure. Prices fluctuate based on market conditions and availability.

Labor Costs: The wages paid to skilled and unskilled workers involved in the construction process. This includes naval architects, engineers, welders, electricians, and other tradespeople.

Equipment Costs: The cost of procuring and installing machinery, engines, navigation systems, and other essential equipment. These costs vary based on the specifications and quality required by the vessel's design.

Overhead Costs: These include administrative expenses, facility maintenance, and utility costs associated with operating the shipyard. Overheads are allocated proportionally to each project.

Project Management: Costs associated with planning, coordinating, and managing the construction project. This includes salaries of project managers and associated administrative staff.

Financing Costs: Interest and fees related to financing the construction project, if applicable. This also includes costs of insurance and guarantees required during the construction period.

7. Methods for estimating production costs

Different methods of estimation and costing exist nowadays with some being more complex than others. There are two basic methods used for estimating the cost of production for a shipyard, the top down and the bottom-up methods.

7.1 Top-Down (macro, cost-down, or historical) approaches

These include empirical, statistical, and closed-form equations, based on the comparison and extrapolation of established data from objects, in this case ships, with a technical similarity. These methods are used in the initial design phases like concept design and preliminary design where there is fewer detailed information available. Top-down methods are used when the information available is adequate to recognize a similarity to previous objects.

The top-down approach determines the production costs using global parameters such as the weight of the hull, the block coefficient, and the length of a vessel. The relationships between cost and those global parameters are derived from evaluations taken from previous ships. Consequently, the top-down approach is only applicable if the new design is similar to one of those previous ships. The cost estimation factors in this approach reflect past practices and experience. Despite its popularity and frequent references in the literature, top-down approaches have several serious disadvantages, which are often overlooked or concealed. This approach uses only global information

and is therefore incapable of reflecting any local changes or design details that improve producibility.

It is usually based on weight, so any change that increases weight will automatically increase the cost estimate, regardless of the actual effect on cost. For example, extremely lightweight designs may drastically increase the number of required hours, while large frame spacing may increase weight but decrease necessary man-hours. These nuances are often not reflected in the approach.

The approach relies on historical data, based on historical designs and production methods. Given the revolutionary changes though that have taken place in the production technology over the past decade, the data and formulae may be outdated and do not reflect elements such as new approaches in structural design or production technology.

The approaches were likely based on inaccurate data even when they were first derived. Shipyards are traditionally poor sources of cost information, with data frequently modified by pressures from first-line managers and other factors.

This approach is not suitable for structural optimization, as there is no link between cost and design variables (Volker Bertram, 2022), (Shetelig, 2013).

7.2 Bottom-Up (micro, cost-up, or engineering analysis) approaches

This method involves direct rational assessment. The bottom-up approach breaks down the project into individual elements of work and builds up a cost estimate through detailed engineering analysis. For each work process, the number of necessary man-hours is computed by multiplying the average man-hours per unit by the number of units for this work process. Units for a work process could include the number of frames and plates requiring bending or meters of weld. The total number of necessary man-hours is then the sum of all man-hours for the individual work processes. These man-hours are converted into cost by multiplying the man-hours for each work process by the shipyard-specific cost factor (monetary unit/man-hour). The sum of all work processes yields the total labor cost, while material costs are estimated similarly. The depth of differentiation of the individual work processes is chosen appropriately. While the bottom-up approach requires more effort and detailed information than the top-down approach, it also captures differences in design elements and is more suitable for

scantling and shape optimizations. However, this approach is currently not available in most shipyards, nor are there historical databases from which it could be developed (Volker Bertram, 2022), (Shetelig, 2013).

work process	man-h/unit	units	man-h	Euro/man-h	Euro
Bending frames					
Bending plates (single curv.)					
Bending plates (double curv.)					
Manual welding					
Automatic welding					
TOTAL (labor)					
Material			**units**	**Euro/unit**	**Euro**
Frames					
Plates					
Welding material					
TOTAL (material)					
TOTAL (lab.+mat.)					

Table 1 Bottom-up approach for estimating production costs (Volker Bertram, 2022)

8. Cost Accounting: Definition, Scope, Objectives, and Significance

Cost accounting is a branch of accounting that focuses on recording, analyzing, and managing costs associated with the production or delivery of goods and services. Cost accounting is defined as the process of accumulating and retaining cost data related to work orders, including labor hours, material quantities, and miscellaneous costs, and automatically charging them to specific cost centers, areas, and departments within an organization.

The development of cost accounting and control in recent years has been aligned with the developments in computer applications technology and it is used for the provision of numerical details and cost information to internal management for decision-making, planning, and control. Unlike financial accounting, which is geared towards external reporting, cost accounting is primarily used for internal purposes within a working environment. The scope of cost accounting is extensive, encompassing several critical areas (Science Direct - Cost Accounting, 2024).

First, the measurement of costs starts with identification and measurement of costs associated with various activities, processes, and products. Then follows the cost analysis, which entails analyzing cost behavior, identifying cost drivers, and

determining the profitability of products and services. Additionally, cost control is implemented to manage and reduce waste, thereby improving a company's efficiency. Cost planning is another crucial stage, involving the preparation of budgets and forecasts to guide future activities and resource allocation based on which management could proceed with potential projects. Furthermore, cost reporting provides relevant cost information to management for strategic decision-making. Finally, performance evaluation assesses the efficiency and effectiveness of operations and cost management strategies applied. The primary objectives of cost accounting include several key elements. Cost ascertainment aims to determine the cost of products, services, or activities accurately. Cost control focuses on monitoring and managing costs to ensure they do not exceed budgeted amounts. Cost reduction identifies opportunities for reducing costs without compromising quality. Profitability analysis examines the profitability of products, services, and departments. Decision-making is enhanced by providing management with the necessary cost information for making informed decisions. Lastly, inventory valuation involves accurately valuing inventory for financial reporting and operational purposes (Kaplan, 1998).

Cost accounting plays a significant role in the management of an organization, and its importance can be highlighted through several points. Enhanced decision-making is achieved by providing detailed cost information, to assist the management in making informed decisions regarding pricing, budgeting, and resource allocation. Improved efficiency is realized through cost control and reduction measures, which help in reducing wastage and enhancing operational efficiency (Hilton, 2016).

Moreover, profit maximization is facilitated by profitability analysis, which helps identify the most and least profitable products and services, guiding strategic decisions. Budgetary control is supported by cost accounting through the preparation and monitoring of budgets, ensuring that actual costs align with budgeted figures. Finally, regulatory compliance is ensured by maintaining accurate cost records, which is essential for financial reporting and adherence to regulatory standards, as well as the prompt provision of data when requested (Bhimani, 2012).

8.1 Methods of Costing

In the field of cost accounting, several methods are employed to determine the cost of products and services. Taking into consideration that every organization has a different

nature and characteristics, it is necessary to employ different costing systems to ascertain the costs involved. These methods include the job order costing, the batch costing, the activity-based costing, the contract costing, and the process costing. Each method is tailored to suit specific types of organizations and business environments (Bhimani, 2012).

8.1.1 Job Order Costing

Job order costing or specific order coting is used when products are manufactured based on the order specifications provided by the customer, for example a new order made by a potential shipowner for a new build vessel. Each job or order is treated as a unique project, and costs are accumulated separately for each job. This method is particularly functional in industries where products are custom-made, such as in shipbuilding, manufacturing firms producing bespoke items, construction projects, and engineering works. Costs are linked to each job, and the total cost includes direct materials, direct labor, and a share of manufacturing overheads. The primary objective is to determine the cost and profitability of each job, facilitating precise billing and cost control of a project. To monitor the individual costs different documents may be used such as the materials requisition form, the job cost sheet and the time ticket. The material requisition list includes elements like a description of the materials used, the date when a material was used from a company's inventory, the exact number of materials used and the price per unit of each material. The job cost sheet is used to trach the job implementation and includes details such as the date the job started and ended, customer information and contact details, the date of dselivery to a customer, what materials were used and other specific information. Finally, the time ticket includes data related to the specialized staff employed during a certain project such as employees name, dates and hours of employment, employee's hourly rate etc. (Drury, 2015), (Horngren, 2018).

The job order costing method has both advantages and disadvantages. Some of the main are the following:

Job Order Costing Advantages:

- It provides a detailed analysis of the elements of cost related to a project which is very useful during the preparation of cost estimates.

- The data produced by the application of the method are quite helpful in the preparation of future budgets.
- It facilitates the assertion of the cost and the profit or loss related to each job separately.
- It provides a company's management with significant information which lead to the identification of the profitability of a project.

Job Order Costing Disadvantages:

- The job costing method relies of historical data and as such it cannot always be helpful for the cost control process.
- Costs are usually being collected from a large number of smaller projects. As a result, the possibility of errors in cost collection is higher in job order costing.
- The use of the method may add to the overall costs since it involves more clerical work for cost collection and more detailed supervision.

8.1.2 Process Costing

Process costing is a method applicable in industries where production is continuous, and products are indistinguishable from each other. It is used when the manufacturing process is unceasing, and it is difficult to establish how much of each material is used and how much time has been invested in each unit of the final product. Therefore, in process costing, costs are determined by the production process instead of by the product or by the job. This method works well for manufacturers of products and it is used in industries such as chemicals, petroleum, textiles, and food processing. In process costing, costs are accumulated for each process or department over a specific period, and the total cost is then averaged over the units produced during that period. This method provides a systematic approach to cost allocation, enabling an accurate product costing and inventory valuation. It also helps in performance evaluation and cost control across different stages of production. Some companies though might choose a hybrid system, using process costing to account for mass producing a part and using job order costing to account for assembling some of those individual parts into a custom product. The below table summarizes the use of these two accounting methods (Drury, 2015), (Horngren, 2018).

Job Order and Process Cost Systems

	Job Order Cost System	Process Cost System
Product type	Custom order	Mass production
Examples	Signs, buildings, tax returns	Folding tables, toys, buffet restaurants
Cost accumulation	Job lot	Accumulated per process
Work in process inventory	Individual job cost sheets	Separate work in process inventory department
Record keeping	Individual job cost sheets	Production cost report

Table 2 Differences between job order costing and process costing (Mitchell Franklin, 2019)

8.1.3 Batch Costing

Batch costing includes the accumulation of costs during the production of a group or batch of identical or similar products. It is applied when products are manufactured in batches, rather than as individual units. Each batch is treated as a separate job, and costs are accumulated for the entire batch. The costing procedure for batch costing is similar to that of job costing. The difference lies in the fact that a batch becomes the cost unit rather than a job. Each batch (or group of identical products) is allotted a serial number (also known as a batch number) and the presentation of the various elements of cost is made in the form of a statement known as a batch cost sheet.

The batch cost sheet includes the cost of any direct materials, direct labor, and direct expenses that can be directly identified with a particular batch.

This method is suitable for industries where products are produced in limited quantities, such as in the pharmaceutical, food production, and garment manufacturing industries. The total cost of the batch is divided by the number of units produced to determine the cost per unit. The formula for batch costing is as follows: Batch Costing = (Total Cost of Goods Produced -Batch/ Number of Units Produced) x Number of Units in Batch (Finance Strategies -Batch Costing by True Tamplin, 2023).

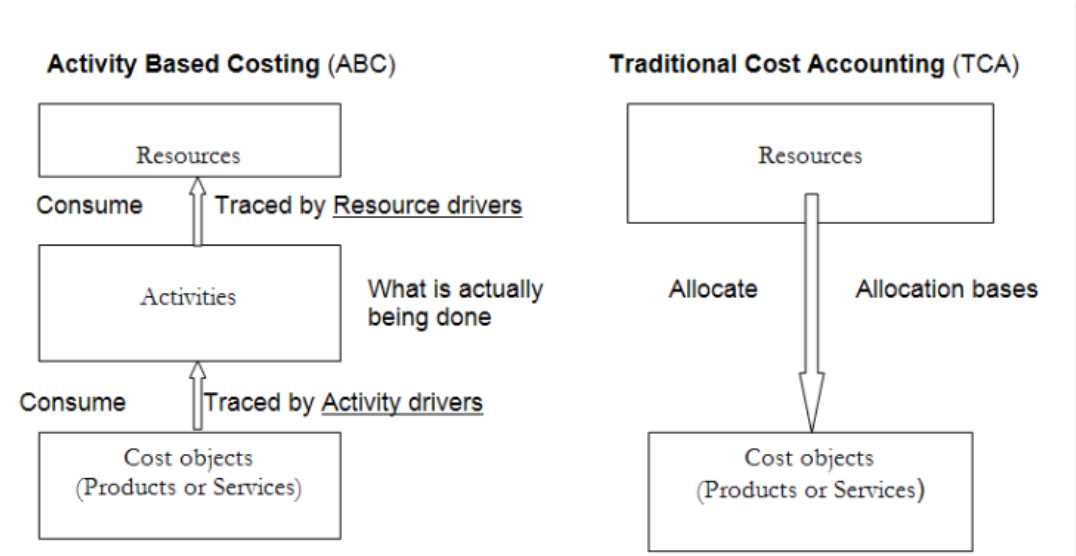
Batch costing leads to reduction of accounting work since the products are treated as a homogenous job and it also ensures accurate cost allocation, helping in pricing decisions, inventory valuation, and profitability analysis (Drury, 2015), (Horngren, 2018).

8.1.4 Activity-Based Costing (ABC)

Activity-based costing (ABC) is a product costing system which allocates indirect costs to products depending on their relative consumption of company resources. It is a more refined approach that allocates overhead costs to products based on the activities required to produce them. Over the last decades, ABC usage has been extended to various service industries as a tool of management accounting to

monitor and manage business performance (Prasad, 2017)

Unlike traditional costing methods, which often allocate overheads based on a single cost driver like labor hours or machine hours, ABC identifies multiple cost drivers and allocates costs accordingly. This method provides a more accurate reflection of the resources consumed by each product. ABC is particularly beneficial in complex manufacturing environments with diverse products and high overhead costs. It helps in identifying non-value-added activities, improving cost management, and enhancing strategic decision-making. The below figure presents the stages that ABC uses for cost allocation, the cost drivers and the relationships between the resources, activities and objects (Drury, 2015), (Horngren, 2018).



Activity based costing (ABC) versus traditional cost accounting (TCA) systems

Table 3 The Activity based costing versus traditional accounting (Prasad, 2017)

There are 7 basic steps followed during the Activity-Based Costing method:

Step 1: Identify the products which are the chosen cost objects. During this step, the main activities (which cause overhead expenses) are identified. Such activities include web site design and maintenance, order processing, product marketing, telephone support, product handling, and product shipping. The number of main activities identified is determined by the level of accuracy and reliability desired.

Step 2: Recognize the direct costs of the products.

Step 3: Choose the activities and cost-allocation bases to use for allocating indirect costs to the products.

Step 4: Identify the indirect costs associated with each cost allocation base (activity).

Step 5: Determine the rate per unit of each cost-allocation base (activity) used to allocate indirect costs to the products.

Step 6: Evaluate the indirect costs allocated to the products.

Step 7: Calculate the total costs of the products by adding all direct and indirect costs assigned to the products (Prasad, 2017).

8.1.5 Contract Costing

Contract costing is used for large-scale, long-term projects such as construction contracts, shipbuilding, and infrastructure development. According to the Chartered Institute of Management Accountant (CIMA), it refers to "a type of particular order costing that applies when work is performed to the customer's unique specifications and each order is of extended duration". Each contract is treated as a separate cost unit, and costs are accumulated over the duration of the contract which usually lasts more than a year. This method involves detailed tracking of costs associated with materials, labor, and overheads specific to each contract.

There are two types of contracts. The first type is the fixed price contract. In this type of contract, the price is usually fixed and agreed between the parties involved in advance. Tenders are invited, providing details of the contract in order to fix up the contract price. After the agreement between the parties, any additional work may be charged separately. The agreement may include provisions that allow the contractor to pass to the contractee any additional cost incurred due to price rise of factors such as materials or wages awards, etc. (Finance Strategists - Contract Costing by True Tamplin , 2023).

The second method of contract costing is the cost-plus contract method. Cost-plus contract is a contract in which the price is not agreed between the parties in advance. This type of contract is entered into when it is impossible to calculate future price or cost accurately due to the lack of past records and experience or because of peculiar circumstances. The contract price is determined later by adding a fixed percentage of profit to the total cost of the contract. Different elements and expenses type which are considered in ascertaining the cost of the contract, are agreed upon in advance (Drury, 2015), (Horngren, 2018).

The main objectives of contract costing are the following:

- The comparison of actual and expected prices
- A thorough cost evaluation aiming at the establishment of a foundation for cost-plus pricing.
- The calculation of profit for a long-term contract
- Management assistance in resource allocation.

Contract costing helps in monitoring project expenses, ensuring that costs stay within budget, and facilitating progress billing to clients. It is essential for managing financial performance and ensuring profitability in large projects.
The contract costing method provides significant challenges to cost control. These issues are common and involve the consumption of materials and inefficiencies, supervision and utilization, and plant and equipment damage and loss.

The contract costing method has both advantages and disadvantages as per below (Economics Dicussions - Madhuriben K., 2024):

Advantages

- The contractor bares the costs of the contract’s such as labor, materials, other fixed charges etc.
- Each customer receives a detailed contract account which includes the costs expended and the work completed to date.
- Control is also maintained over defects caused by the lack of quality.
- Retention money becomes motivates the production of high-quality work.

Disadvantages

- The main drawback is that the, method requires time.
- The escalation clause may not be acceptable by a customer.
- Profits may be miscalculated due to a lack of bookkeeping.
- It is necessary to monitor the market circumstances at all times.
- The increased time may cause challenges in the execution of tasks.

Both job costing and contract costing belong to the same category of specific order costing. At both practices, the implementation starts after the receipt of the order from the customer and according to specific instructions. However, there are some key differences between the two methods:

- Contract is of big size compares to the job which is of smaller size.
- Contract work is done at work site while the job takes place in the company's premises.
- Job takes less time to be completed (less than a year) while contract takes a long period of time to be completed (more than a year).
- In contract costing heavy investment and expenses take place compares to job costing.
- In contract costing major expenses are of direct nature and are related to particular contract. In job costing both direct and indirect expenses are equally considered.
- Contracts are mainly related to construction and engineering fields while jobs are related to the production area.
- Contracts apply to large scale projects while job costing for small scale jobs.
- Profits on contract can be calculated on the incomplete contracts, depending on the work completed. On jobs, profits are to be calculated on the completion of jobs (Economics Dicussions - Madhuriben K., 2024)

9. Cost Accounting Techniques

In addition to the various methods of costing, several cost accounting techniques are employed to manage and control costs effectively. Each technique serves a unique purpose and aims at enhancing the efficiency and profitability of a company.

9.1 Main costing techniques

Some of the main costing techniques include the standard costing, the marginal costing, the variance analysis, and the budgetary control.

9.1.1 Standard Costing

Standard costing is a technique that involves setting predetermined costs for products and services. These standard costs are based on historical data, industry benchmarks, and management's expectations. The primary purpose of standard costing is to serve as a benchmark for evaluating actual performance. By comparing actual costs with standard costs, management can identify variances and take corrective actions. This technique is particularly useful in manufacturing environments where production processes are repetitive and predictable. Standard costing facilitates cost control, pricing decisions, inventory valuation, and performance measurement (Bhimani, 2012), (Horngren, 2018).

9.1.2 Marginal Costing

Marginal costing, also known as variable costing, focuses on the variable costs associated with production. In this technique, only variable costs (direct materials, direct labor, and variable overheads) are considered when determining the cost of a product. Fixed costs are treated as period costs and are not allocated to individual products. Marginal costing provides valuable insights into the contribution margin, which is the difference between sales revenue and variable costs. This technique is useful for decision-making, particularly in pricing, product mix decisions, and analyzing the impact of changes in production levels on profitability. It aids in understanding the behavior of costs and their impact on the overall financial performance of the organization (Bhimani, 2012), (Horngren, 2018).

9.1.3 Variance Analysis

Variance analysis is a technique used to analyze the differences between actual costs and standard or budgeted costs. These differences, known as variances, are classified into favorable and unfavorable variances. Variance analysis helps in identifying the reasons for deviations from the expected performance and provides a basis for corrective actions. This technique is crucial for cost control and performance

evaluation. It involves analyzing variances related to materials, labor, and overheads, enabling management to pinpoint inefficiencies and take appropriate measures. Variance analysis enhances transparency and accountability within the organization by highlighting areas that require improvement (Bhimani, 2012), (Horngren, 2018).

9.1.4 Budgetary Control

Budgetary control is a comprehensive technique that involves preparing budgets for various activities and comparing actual performance with budgeted figures. Budgets serve as financial plans that outline expected revenues, costs, and expenditures over a specific period. Budgetary control helps in ensuring that organizational activities are aligned with strategic objectives and financial goals. By monitoring actual performance against budgets, management can identify variances and implement corrective actions to stay on track. This technique promotes efficient resource allocation, cost control, and financial discipline. Budgetary control also facilitates long-term planning, performance evaluation, and informed decision-making (Bhimani, 2012), (Horngren, 2018).

9.2 Groups subdivision in Shipbuilding

It is common during the shipbuilding process that the project is divided into smaller groups to address the cost of different parts of the ship.

During the life cycle of a ship, which begins from the conceptual design through detailed design and results in the construction to operation and maintenance, there is a significant amount of information exchanged between the parties involved. The led to naval architects, shipbuilders, ship owners, regulatory bodies and marine suppliers to look for a common ground for specification indexing, drawing, numbering and cost accounting (Stopford, 2009).

The SFI Group System is a classification system for ship technical and cost information initially developed by shipyards. Input was provided both by worldwide shipyards and by shipowners and the system was first tested in 1972. The main criteria for designing the SFI Group System were that it must be suitable to all users, it must be applicable to all ships types, it must be simple and easy to understand and finally it must be capable of future expansion. The SFI Group System is built up as a three-digit decimal classification system with eight main groups of a vessel’s different systems that is applicable to most ship types. The eight main categories are: ships general, hull,

equipment and cargo, ship equipment, equipment for crew and passengers, machinery main components, systems for machinery main components, ship systems (McConnell, 1977), (Fonseca, 2014).

However, when it comes to cost investigation, the technological groups can be batched into five technological categories and combine the subcategories in order to examine the ship from a tool perspective.

By the combination of the SFI system's categories the ship can be grouped in the following categories:

- Hull
- Deck Machinery
- Propulsion Systems
- Auxiliary machinery and handling equipment
- Ship General. common systems and costs (McConnell, 1977), (Fonseca, 2014).

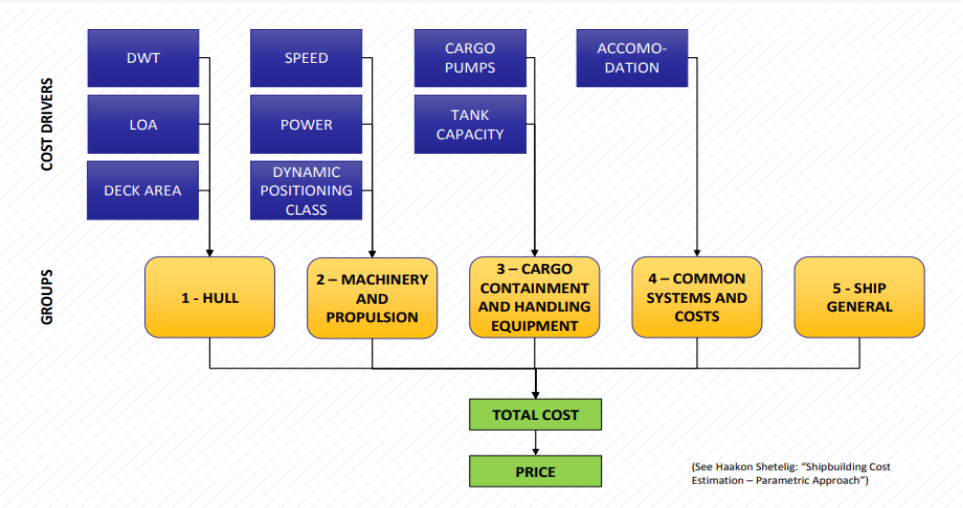


Table 4 Relation between cost drivers and technical groups (NSPR Joint Panel Meeting, 2015)

9.3 Costs & Overhead in Shipbuilding

In the shipbuilding industry ship design and construction costs can be sorted into three basic categories: direct labor, direct material, and overhead. Generally, the overall cost proportions in shipbuilding are about:

- Direct material 40%
- Direct labor 24%

- Overhead 36%

Costs are mainly defined as direct costs, which include raw materials, purchased components, production work hours, design work hours, and subcontracted work.

Direct material costs are the costs of materials used in the production process to produce a ship ready to be delivered to the shipowner. Direct labor cost are labor expenses associated with the placement and employment of labor to handle building process activities, which are essential to managing any repair equipment/facilities

Some costs can be considered direct or indirect at the discretion of a company's management. Direct costs (direct labor and direct materials) are accrued under work breakdown structure cost objects and are attributed directly to the shipbuilding contract. Both the direct material and labor are identified with a single final cost objective (ship or contract) (James E. Rogal, 2016).

Overhead costs are residual costs that includes all other costs which are note treated as direct costs and include a wide variety of costs incurred in the operation of the shipyard which are not directly chargeable to particular ship contracts. Overhead costs encompass indirect material costs, indirect labor costs, and other charges required for successful completion of the production process. They include items such as interest on bank loans, rates and taxes, insurance, electricity, telephone and postage, salary costs of managers and office staff, etc. Some modern management shipbuilding businesses do not perform the complete building work with their employees. When many shipyard companies nowadays have completed a restoration process, ties to other industries are noticeable. These industries, which could also generate materials, completed or semi-finished items, services, or labor, are called maritime industry supporting sectors Overhead costs are mixture of costs, some are variable, some are fixed, and some have both fixed and variable elements. Many are linked to the size and capacity of the yard, which can only be changed over the long run planning horizon. The total overhead expenditure is usually calculated at the end of the fiscal year and expressed as a percentage of the labor cost. An increase in throughput can bring a positive reduction in the overhead rate, but a recession in demand forces could result to an increase at a most unwelcome time. The percentage of fixed to variable overhead reflects the shipyard's capital intensity, the level of production technology, and the corporate strategy of the shipyard's owner (James E. Rogal, 2016).

The consumption of construction materials in one of the main concerns of the shipbuilding industry to save building costs. The cost of steel in hull construction is

about 8%-15% of the total cost of a commercial ship. Moreover, the weight of the lightship over the total weight is about 14% for tanker vessels, 30% for bulk carriers, 35% for container ships. Therefore, the design and optimization of a ship hull have become significant in the reduction of material, labor, and operational costs (Azhar A., 2022), (James E. Rogal, 2016).

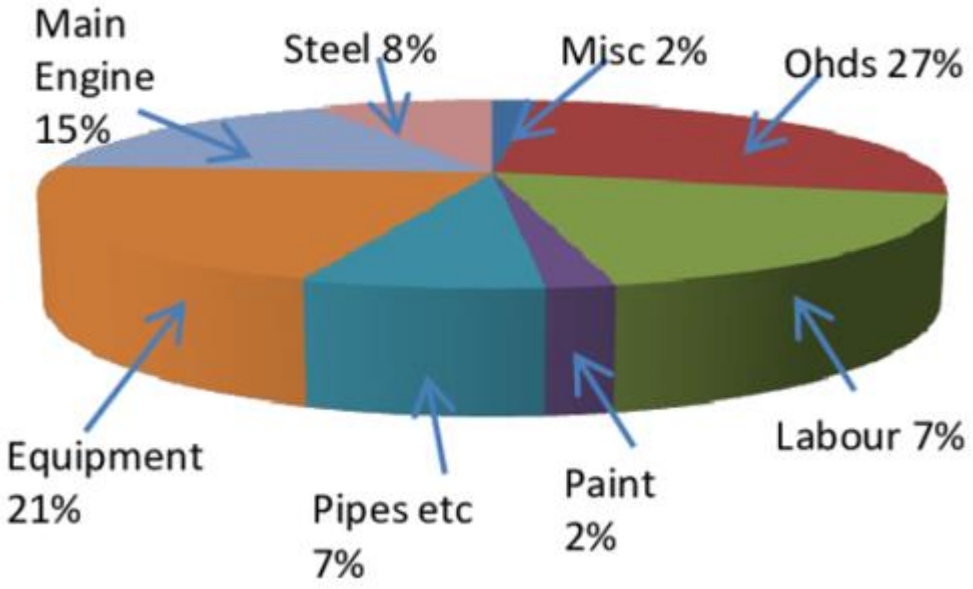


Table 5 Typical New Build Cost Breakdown (Research Gate, 2015)

9.4 Fixed, variable and semi-variable costs

The separation between fixed and variable costs is a key concept in overhead cost analysis. Fixed costs "continue unchanged in total within a relevant range despite wide fluctuations in volume or activity." Variable costs "change in total in direct proportion to changes in volume or activity" (Ralph S. Polimeni, 1984).

9.4.1 Fixed Costs

Fixed costs are the costs that do not change during the process of production or a new ships' building process, in the case of a shipyard. The basic characteristic of fixed costs is that they remain unaltered and they are of great necessity to keep a business or a company fully functional. These costs remain fix, irrespective of the number of ships being built at the same time. Unlike variable costs that are affected by the amount of output, fixed costs are payable, even if the production or a project are terminated or are not taking place. Managers' and other administrative staff salaries for example, are

considered to be fixed costs, since they remain the same during a shipbuilding project. The rent payable by the shipyard for the necessary facilities and the shipyard's offices is also considered a fixed cost considering that it remains stable.

Depreciation of equipment and machinery is also considered a fixed cost. The expense of depreciation remains constant over a tangible asset's useful life in spite of how much it is being used. The expense maintains stable regardless the activity or the production taking place and it is irrespective of the fact that a shipyard might be constructing one or ten ships. Assets such as equipment, machinery and cranes are used over a long period of time and are depreciated annually to demonstrate the change in value (Horngren, 2018), (Garrison, 2020).

9.4.2 Semi-Variable Costs

Semi variable costs are a mixture of fixed and variable costs. As a result, they might increase with the increase of output but not necessarily at the same proportion to the production level. Examples of semi variable costs in the shipbuilding sectors are salaries which are related to the performance and a conclusion of a certain project. Salaries under a contact are fixed, however it is common for project managers to be compensated with an extra commission or bonus upon completion of a project and the stage of performance, an amount irrespective to the agreed salary payable. Moreover, other costs related to machinery and equipment used, apart from the fixed ones, that might occur during the usage, are considered to be semi-variable costs (Horngren, 2018) (Garrison, 2020).

9.4.3 Variable Costs

Variable costs are those costs that interact with the level of output or production. These cost change according to the number of ships being built by a shipyard and increase or decrease respectively. The required quantity of materials for instance changes with the number of the new build project taken by a shipyard. Labor salaries of constructors and employees, working under hourly payment terms also change depending on the hours and the days spent upon completion of the construction process. Utility bills and expenses such as the electricity and communication cost, are also considered a variable cost since the increase of electricity usage results to higher bills payable by a company (Garrison, 2020), (Horngren, 2018).

"The Builder shall, at its own cost and expense, provide the Buyer's Representative and assistants with reasonable office accommodation and facilities (including communication equipment, such as telephone, fax and appropriate internet access, and printers or a connection to the Builder's printers) as the Buyer may reasonably require. These costs are usually agreed in advance between the potential shipowner and the shipyard as per the below clause mentioned in a new build contract:

"*The Builder shall, at its own cost and expense, provide the Buyer's Representative and assistants with reasonable office accommodation and facilities (including communication equipment, such as telephone, fax and appropriate internet access, and printers or a connection to the Builder's printers) as the Buyer may reasonably require. The Buyer shall bear the costs of all communication expenses arising from the use by the Buyer's Representative and assistants of the communications equipment provided by the Builder. Such expenses shall be payable by the Buyer on receipt of an invoice from the Builder in accordance with Clause 15(b) (Payments - Payment for Modifications and other items).)* (BIMCO, 2024)

Cost Category	**Description**	**Estimated Cost (USD)**	**Actual Cost (USD)**	**Variance**
Fixed Costs	Fixed wages, rent	100.000,00 USD	100.000,00 USD	0,00 USD
Labor Costs	Engineers, technical superintendents, electricians	500.000,00 USD	600.000,00 USD	-100.000,00 USD
Materials and Stores Costs	Equipment, materials, tools, electronic stores, welding equipment etc.	1.000.000,00 USD	800.000,00 USD	200.000,00 USD
Semi-Variable costs	Maintenance expenses, electricity usage	400.000,00 USD	700.000,00 USD	-300.000,00 USD
Toal Cost		**2.000.000,00 USD**	**2.200.000,00 USD**	**-200.000,00 USD**

Table 6 An example of Cost Breakdown for a New Build Project (Research Gate , 2024)

9.5 The Job order Costing Method in Shipbuilding

The job order accounting method as mentioned above is a practice where each project is treated individually, a particular job. In the case of shipbuilding, is new build ships is considered a unique project, under a specific contract which is being built in

accordance to the specifications, designs and requirements of the potential owner making the job order method a commonly used one in the shipbuilding sector.

Under this method, all costs and overheads are attributed to a certain new build order, treated as a unique project of the shipyard. Initially, a new order is placed to the shipyard by the interested shipowner. A unique project number is allocated to the project to act as a reference for the allocations of all related costs and procedures that will follow. Before the usage of any material in the job, a materials requisition form is created which is form that lists the quantity and cost of the direct materials used on the specific job. The form is used to control the flow of materials out of a company's inventory into production. It also provides the information needed to record the cost of raw materials in the system. Moreover, a direct labor time ticket is also created, which is a document that shows time a worker spent on the specific job.

All costs, related to materials, labor and overheads are documented and reported under the specific job order number. In a job order cost system, all construction costs are recorded on a document called the job cost sheet, that provides a detailed record of the cost incurred to complete a specific project, i.e., job. Costs that are directly attributed to the project are charged directly to the project while overheads such as utilities are usually allocated based on a percentage rate. Upon completion of the project the actual costs are compared to the estimated one, and any differences in budgets versus actuals variances are further analyzed (Drury, 2015), (Horngren, 2018).

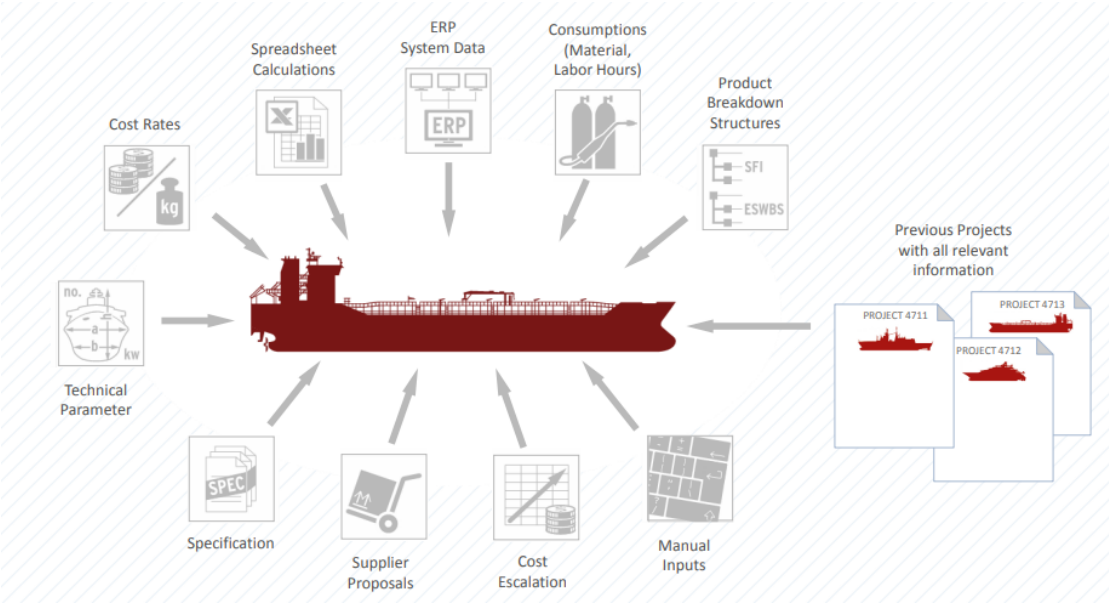


Table 7 Integrated administration of all cost relevant information (NSPR Joint Panel Meeting, 2015)

9.5.1 Budget versus Actual

Budget variance analysis allows companies to identify differences between budgeted and actual costs from projects enabling a more efficient decision making and resource allocation, and provides a clear picture of the overall performance. The analysis also assists in the determination of the causes of variances and is a key element in forecasting. There are different types of budget variances, including revenue variance, expense variance, volume variance and price variance.

The budget variance analysis is of a great significance to companies and can assist an entity as follows:

- **Adjustment of budgets and estimations.** The analysis can assist with the identification of areas where a company exceeded or fell short of budgeted goals, enabling the adjustment of budgets for the improvement the financial performance.
- **Effective allocation of resources.** By obtaining a clear picture of their financial performance, businesses can allocate their resources in a more effective manner, to achieve their financial goals.
- **Improvement of operations.** By detecting the causes of variances, companies can identify areas of operational inefficiencies and take the necessary steps to improve their operations.
- **Measurement of initiative effectiveness.** The analysis can measure the effectiveness of cost-saving initiatives, strategies, and other business initiatives, promoting accountability and continuous improvement.
- **Accurate forecast and plan.** The analysis of variances supports forecasting and long-term planning by providing a clearer picture of past performance and highlighting the areas that require more attention (Garrison, 2020), (Horngren, 2018).

9.5.1.1 The budget versus actuals formulas

The analysis of budget versus actual is a critical financial management tool for all companies and a key indicator of financial performance. The main components used

for the analysis is the budgeted costs and the actual ones. Budgeted are the estimated costs in advance, before the beginning of the project and include all the expected costs usually based on previous, similar projects undertaken by an organization. The actual costs are the incurred ones during the project. Variances, the differences between estimations and actual costs, can be either favorable or unfavorable. Favorable variances occur when the actual costs are less than the estimated ones while the opposite are the unfavorable case. For the analysis of the variances the root causes have to be examined and reported in order to be used for future reference before a new project.

There are two main formulas applied in the variance analysis. The first one is the percentage variance formula and it is calculated as:

- (Actual sales or expenditures ÷ Budgeted sales or expenditures) –1

The second formula is the dollar variance formula which is calculated as:

- Actual sales or expenditures less budgeted value

The analysis of variance in the shipbuilding process is essential for the improvement of performance and better decision making ensuring the viability of undertaken projects (VARETO , 2015).

Conclusion

Shipping plays a vital role in the global economy by facilitating the movement of goods across the world and promoting international trade. Ships are the means that carry cargoes in the safest and most economically efficient manner. The international trading activity, results in financial viability and prosperity of counties and companies around the globe, and its importance cannot be overlooked. Shipping ensures the continuous transportation of raw materials and manufactured goods that drive economic development and globalization. However, the shipping industry is influenced by multiple market, geopolitical and financial factors, each of which must be carefully taken into account to ensure the cost-effective maritime operations.

The shipping market conditions are of huge importance and need to be assessed thoroughly before new ship orders take place. Shipping is a capital-intensive industry, and fluctuations in exchange and interest rates, conditions of financial markets and funds as well as the overall economic and geopolitical environment can significantly impact the viability of investments in new ships. Shipowners and shipyards must closely monitor trends, forecasts and market phases in order to align their strategies with favorable market phases, minimizing risks and maximizing profits. Understanding the cyclical nature of the shipping industry, which is closely tied to global trade volumes and economic health, promotes better decision-making.

Shipyards and shipowners should also consider various aspects before placing or accepting new orders. Shipowners need to assess the prevailing market's fleet requirements, the future market conditions focusing on the supply and demand factors, and the technological advancements that could impact a vessel's efficiency, environmental compliance, and competitiveness. Shipyards, on the other hand, must evaluate their production capacity, must ensure the necessary resource at the most attractive prices, and need to access the ability to meet industry standards. These considerations are essential to avoid overcapacity or missed market opportunities.

The cost element in shipbuilding projects is of huge concern, given the long-term financial commitments and the considerable capital investment required. Shipbuilding costs are influenced by different factors, including raw material prices, labor costs, and compliance with environmental and safety regulations. The complexity of managing

these costs necessitates the application of specialized costing methods to ensure accuracy and control.

Variable cost techniques, such as job order costing, activity-based costing, process, batch and contract costing, provide valuable insights into monitoring and accessing the shipbuilding costs. These techniques help in identifying cost drivers, allocating resources efficiently, and ensuring the financial feasibility of projects. The application of these methods enables shipyards and shipowners to maintain control over budgeted and actual costs, reducing the risk of inefficiencies and enhancing profitability.

Additionally, the implementation of budgetary management is essential in controlling the financially complex shipbuilding projects. Budgetary control ensures that projects are completed within the estimated financial resources, while continuous management helps in adjusting to unforeseen challenges, such as cost overruns or delays. The application of cost control techniques with budgetary management practices lead to more accurate evaluation, better financial discipline, and improved decision-making, contributing to the success of shipbuilding projects.

Shipping is a dynamic industry that requires a comprehensive knowledge and awareness of financial markets, cost management methods, and strategic decision-making by both shipowners and shipyards. Thorough examination of these factors beforehand, coupled with the use of various cost techniques and budgetary control, ensures that the shipping industry remains robust, competent, and efficient in meeting the demands of the global marketplace.

The present study contributes to the literature by expanding the understanding of the financial, operational, and regulatory factors influencing new build projects. It focuses on the variable cost estimation techniques used in the shipbuilding industry, providing insights into how shipyards and shipowners manage costs associated with materials, labor, overheads, and compliance. The study also examines the perspectives of various stakeholders, such as shipowners, shipyards, financial institutions, and regulatory bodies. This approach adds depth to the existing body of work by examining how each stakeholder’s decisions, priorities, and interactions affect shipbuilding projects' overall cost structure and success. Moreover, it highlights the significance of financial strategies like differentiated cost accounting techniques in maintaining profitability, thus contributing to the financial management literature within the shipping industry.

The outcome of this study has important implications for practitioners in the shipbuilding industry. For key parties, such as shipowners and shipyards, the findings provide a framework for better cost management and decision-making during new build projects. The study's analysis of cost estimation methods offers practical tools for optimizing budgets, controlling costs, and improving profitability. Additionally, the insights on market conditions, regulatory compliance, and financing options can guide strategic planning and help practitioners navigate industry challenges more effectively while hedging financial risks.

The study could be further elaborated by analyzing the impact of environmental regulations and technological advancements on shipbuilding costs and strategies. Future research could focus on how new technologies, such as autonomous ships, fuel-efficient engines, or green technologies like alternative fuels (LNG, hydrogen, ammonia), are shaping cost structures and investment decisions in the shipping industry. Moreover, a detailed examination of the increasing impact of environmental regulations, such as the IMO's emissions standards, on the financial aspects of shipbuilding would provide valuable insights. Finally, future studies could incorporate risk management techniques in shipbuilding projects, exploring how uncertainties like fluctuating prices, and geopolitical or unforeseen events affect budget adherence and overall project profitability.

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