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Title: Technical management in Greek Shipping Companies

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Abstract

Shipping is one of the most important sectors of the Greek economy, with Greek shipowners holding international shipping by sea. Ships, whether passenger, bulk carrier or tanker, sail in accordance with a number of international conventions dealing mainly with the safety of the ship crew, the ship and the environment. In addition, the financial characteristics of a ship as well as the method of ship management are a multifactorial field related to the class of ship, the characteristics of the ship's navigation, the characteristics of the route and many other elements. The main purpose of this thesis is to analyze the technical management in Greek shipping companies.

Keywords: Shipping, Transport, Technical

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1. Introduction

The International Convention for the Safety of Life at Sea (SOLAS) is an international maritime treaty that sets minimum safety standards for the construction, equipment and operation of merchant ships. The Convention requires signatory States to ensure that ships flying their flag comply with these standards. The connection between production and consumption is achieved with transport services. Transport is a productive sector of an economy and is divided into three main categories, depending on the means of transport, namely land, sea and air. Despite the increase in air transport, shipping still accounts for the bulk of global transport.

Shipping depends on production. Production is aligned with the concept of gross domestic product (GDP). Therefore, the volume of shipping depends on the growth rate of gross domestic product (GDP). International shipping for a country is transportation to or from the country. in other words, international shipping reflects a country's imports and exports by sea. In contrast, inland shipping evolves transactions within a country's borders. A boat according to the law that applies to each country has certain characteristics and peculiarities. Indicatively, these features refer to the following:

- The ship may consist of components and parts which cannot be separated from the ship in the event of damage or alteration of their substance or destination,
- The ship has no legal personality and is an object and not a subject of the respective legislation of a country,
- The vessel is a mobile thing sometimes with legal aspects, but the law treats it as a property,
- The vessel may be subject to use and economic exploitation,

- The ship has life, emerges (with its construction), lives (if in service) and dies (from scrapping or abandonment)

The ship, due to its constant movement, is subject to legal relations. There is an essential need to visualize these particular features and characteristics that are visible to all involved. The most important of these features are:

- **Name:** The name of each boat is freely chosen by the owner and recorded in the register required along with other details.

- **International Trademark:** Each ship has its own international trademark, consisting of a combination of four letters of the Latin alphabet.

- **Port of Registration:**It is in a way the permanent residence of the ship. The port of registration is freely chosen by the owner.

- **Nationality of the vessel (flag):**The ship is considered to be a floating part of the state whose flag it bears. Proof of nationality arises from the documentation of nationality.

Therefore, the ship is of great importance from the point of view of the public interest, so the state closely monitors and monitors its operating conditions. The basic documents that a ship must carry are:

- Nationality document (Registry certificate)

- Tonnage certificate (capacity)

- Class certificate

- Visitors' log book

- Load Line Certificate

- Crew certificate

- Log books

- Oil record book
- Continuous Synopsis Record

Ships can be classified into two major categories, commercial and non-commercial. The classification of ships into categories is done by various criteria, such as e.g. fuel, their end use, the length of their travels or other criteria. The most common ways of economically exploiting different types of merchant ships are:

- Merchant ships operating regular services between certain ports designated as liners.
- Chartering (Chartering over time, time charter) is another form of exploitation.
- Free chartering, (Spot, voyage) during a voyage or multiple trips, is perhaps the most common form of exploitation.

Other shipping definitions that are important to the shipping industry are:

- **Owner:** This is the chairman of the board, who simultaneously directs the Shipping Company. The **ship manager** carries out the shipping activity without being the owner of the ship. The Master is the one who has the command of the ship.
- **Crew:** The crew members are the sailors.
- **Shipping agent:** The professional responsible for conducting agent operations.
- **Charterer:** The counterparty of the articles of association established between him and the owner. A charter is a contract in which the lessee intends to use, for payment, a ship in whole or in part, to carry out the carriage of means or passengers.

- **Broker:** The person who mediates the drawing up of a charter contract for a fee, which is usually specified in the party to the charter.

The purpose of this work is to study the annual management of operating costs of a ship in terms of technical part and possible methods of reducing them. Both the costs of a ship and the methods of optimizing their limitation are two concepts that depend on various factors and parameters, such as the type of ship, its original design, its size, its cargo, its maintenance, issues related to security, etc. For this purpose, the work first analyzes the characteristics of safety and environmental management in shipping, then presents the shipping accounting of a ship, the description of its financial characteristics, its daily operating costs and the costs associated with the voyage.

2. Management of safety and environment in Shipping SOLAS, MARPOL & MLC.

2.1.1. The international SOLAS convention

The International Convention for the Safety of Life at Sea (SOLAS) is an international maritime treaty that sets minimum safety standards for the construction, equipment and operation of merchant ships. The Convention requires signatory States to ensure that ships flying their flag comply with these standards.

The current version of SOLAS is the 1974 version, known as SOLAS 1974, which entered into force on 25 May 1980. As of November 2018, the SOLAS 1974 Convention had 164 Contracting States, which is 99% of merchant ships around the world. The non-Contracting States to SOLAS 1974 include Bolivia, Lebanon and Sri Lanka. SOLAS in its successive forms is generally considered to be the most important of all international conventions on the safety of merchant ships (IMO, 1974).

The first version of the SOLAS contract was approved in 1914 as a result of the sinking of the Titanic. The contract provided for a sufficient number of lifeboats and other emergency equipment along with safety procedures. However, the 1914 treaty never came into force due to the outbreak of World War I. Following this, new versions were approved in 1929 and 1948 (Aust, 2013).The 1960 Convention was adopted on 17 June 1960 and entered into force on 26 May 1965. It was the fourth SOLAS Convention and was the first major achievement for the International Maritime Organization (IMO). It was an important step forward in modernizing regulations and adhering to technical developments in the shipping sector.

A completely new contract was adopted in 1974, which would allow SOLAS to be amended and implemented within a reasonable time, instead of the previous modification incorporation process, which proved to be too slow. Under the SOLAS 1960 Convention, it may have taken several years for the amendments to take effect, as countries had to submit an application for admission to the IMO. In contrast, under the SOLAS 1974 Convention, amendments are entered into force through a tacit acceptance procedure, allowing an amendment to enter into force on a specified date, unless there are objections to the amendment from an agreed number of Member States.

The 1974 SOLAS entered into force on 25 May 1980, 12 months after its ratification by at least 50 countries. Since then, it has been updated and amended several times, and the contract in force today is commonly referred to as SOLAS, 1974, as amended. (IMO, 1974) In addition, since 1975, the IMO Assembly has decided that the 1974 Convention should in future use only "System International (SI)" metric units.

The 1988 amendments, based on amendments to international radio regulations in 1987, replaced the Morse Code with the "Global Maritime Distress Safety System (GMDSS)" and entered into force on 1 February 1992. The updated list of SOLAS amendments are complied with by the IMO. In 2015, another subsequent amendment incorporated the Container Weight Verification Regulation. This regulation, implemented by the IMO Mar Maritime Safety Committee (MSC), requires that the full weight of the loaded containers be taken before boarding the cargo ship. The announcement of a weight value allowed the introduction of a new protocol Electronic Data Interchange (EDI) ¨ called Verified Gross Mass - VGM ¨ or ERMERAS of involves cooperation between cargo ships, carriers / NVOCC, EDI operators as well as exporters. The regulation stipulates that exporters are ultimately responsible for verifying the weight of containers.

The SOLAS 1974 Treaty contains articles setting out general obligations, etc., followed by an annex divided into twelve chapters, to which two new chapters were added in 2016 and 2017. (IMO, 1974) Of these, Chapter 5 (the often referred to as "SOLAS V") is the only one applicable to all ships at sea, including private and small vessels engaged in local voyages, as well as merchant ships on international voyages. Many countries have transposed these international requirements into national law so that anyone at sea who violates the SOLAS V requirements can be p

rosecuted (Weintrit, 2009).

The following is a brief description of the fourteen chapters that make up the treaty:

Chapter I - General provisions: Registration and research of various types of ships and certification that they meet the requirements of the contract (IMO, 1974). **Chapter II-1 -** Construction, subdivision and stability, engines and electrical installations: The subdivision of passenger ships into watertight compartments so that after possible damage to their hull they maintain their stability (IMO, 1974).

Chapter II-2 - Fire safety, fire detection and fire extinguishing: Fire safety provisions for all ships, with detailed measures for passenger ships, cargo ships and tankers (IMO, 1974).

Chapter III - Various rescue tools and arrangements: Various lifeboats and arrangements, including requirements for yachts, lifeboats and lifeboats depending on the type of ship. The specific technical requirements are provided in the Life-Saving Appliance (LSA) code (IMO, 1974).

Chapter IV –Radio communications: The Global Maritime Distress Safety System (GMDSS) ¨ requires passenger and cargo ships on international voyages to carry radio equipment, including Satellite Radio for Radio (Emergency) - EPIRBs) ¨ and Search and Rescue Transponders (SARTs) ¨. (IMO, 1974)

Chapter V - Navigation safety: This chapter requires governments to ensure that all vessels are adequately and effectively manned in terms of safety. It sets requirements for all vessels in terms of voyage and transit planning, awaiting careful evaluation of all proposed voyages by all on board. Every seafarer must take into account all possible risks to navigation, weather forecasts, tidal forecasts, crew capacity and all other relevant factors (Weintrit, 2009). It also adds to the obligation for all shipowners to provide assistance to those in distress and controls the use of rescue signals with specific requirements regarding emergency and emergency messages.

Chapter VI - Cargo transportation: Requirements for the placement and securing of all types of goods and containers (containers) except bulk liquids and gases (IMO, 1974)

Chapter VII - Transportation of dangerous goods: Requires the transport of all types of dangerous goods in accordance with the International Bulk Chemical Code (IBC), the International Code of Construction and Equipment of Ships Carrying Liquefied Gas (The International Code of Construction and Equipment of Ships Car Liquefied Gases in Bulk (IGC) ¨ and the International Maritime Organization Dan 1974 Goods Code (IMDG). (IMO, 1974)

Chapter VIII - Nuclear ships: Ships with nuclear power are required, in particular with regard to radiation hazards, to comply with the Nuclear Merchant Ship Safety Code (IMO, 1974).

Chapter IX - Management for the safe operation of ships, requires every ship owner and every person or company taking responsibility for a ship to comply with the International Safety Management (ISM) 1974 (IMO, 1974).

Chapter X - Safety measures for high-speed craft: Makes the International Code of Safety for High-speed Craft (HSC) mandatory ¨.

Chapter XI-1 - Specific measures to enhance maritime safety: Requirements for the bodies responsible for conducting investigations and inspections.

Chapter XI-2 -Specific measures to enhance maritime security: Includes International Ship and Port Facility Security Code (ISPS Code) ¨. It confirms that the role of the Master in maintaining the safety of the ship cannot be limited by the Company, the charterer or any other person. Port facilities must conduct security assessments and develop, implement and review port facility security plans. It controls the delay, detention, restriction or departure of the ship from port. It requires ships to have a safety warning system, as well as details of other measures and requirements (IMO, 1974).

Chapter XII -Additional safety measures for bulk carriers: Contains special construction requirements for bulk cargo vessels over 150 meters. (IMO, 1974)

Chapter XIII - Verification of compliance: Makes the control system of the Member States of the International Maritime Organization (IMO) mandatory from 1 January 2016.

Chapter XIV - Safety measures for ships sailing in polar waters The Chapter makes mandatory, from 1 January 2017, the Introduction and part I-A of the International Code for Ships Sailing in Polar Waters (Polar Code).

2.1.2. The International Convention of MARPOL 73/78.

The International Convention for the Prevention of Maritime Pollution (MARPOL) by the Ships of 1973 as amended by the 1978 Protocol also known as MARPOL 73/78, is one of the most important international conventions for the marine environment. It was developed by the IMO in an effort to minimize pollution of the oceans and seas, including oil and air pollution. The purpose of the contract is to preserve the marine environment in an effort to completely eliminate pollution from oil and other harmful substances and to minimize the accidental leakage of such substances.

The original MARPOL Convention was signed on 17 February 1973, but did not enter into force on the date of signature. The current convention is a combination of the 1973 Convention and the 1978 Protocol, which entered into force on 2 October 1983. Since January 2018, 156 countries have signed the Convention, which translates to 99.42% of the world shipping power.
All ships flying the flag of the countries that have signed the MARPOL Convention are subject to its requirements, regardless of the voyage. (Copeland, 2008)

MARPOL is divided into annexes according to different categories of pollutants. These annexes as well as their content are the following:

Annex I.MARPOL Annex I entered into force on 2 October 1983 concerning the discharge of oil into the marine environment. It includes the criteria for the disposal of oil provided for in the 1969 amendments to the International Convention for the Prevention of Pollution (OILPOL) of 1954. Defines the design characteristics of tankers designed to minimize oil in the ocean during the operation of the ship and in case of accident. It provides regulations on the treatment of water from engine rooms for all large merchant ships and waste from tank cleaning. It also introduces the concept of "Special Marine Areas (PPSE)" which are considered to be at risk of oil pollution. The dumping of oil in them is completely forbidden, with a few exceptions. (Barnea, 2014) The first half of MARPOL Annex I concerns engine room waste. There are several generations of technologies and equipment that have been developed for waste prevention such as: O Oily Water Separators (OWS) ¨, Oil Oil Content Meters (OCM) ¨ and port reception facilities.

The second part of Annex I to the MARPOL Convention deals more with the cleaning of cargo areas and tanks. "Oil Discharge Monitoring Equipment (ODME)" is a very important technology listed in Annex I of the MARPOL Convention and has contributed significantly to the improvement of sewerage facilities in these areas. The oil logbook is another integral part of MARPOL Annex I, which helps crewmembers record and monitor, among other things, sewage discharges.

Annex II: Annex II to MARPOL entered into force on 6 April 1987. It sets out in detail the rejection criteria for the elimination of pollution by harmful liquid substances carried in large quantities. Separates substances and introduces detailed business standards and measures. Disposal of pollutants is only permitted in special reception facilities, and in any case, waste containing contaminants within 12 miles of the nearest land is not permitted. In addition, strict restrictions are provided for "special areas" (Barnea, 2014).
Annex II covers the International Bulk Chemical Code (IBC) ¨ in conjunction with Chapter 7 of the SOLAS Convention. Tankers built before 1 July 1986 must comply with the requirements of the Code of Construction and Equipment of Ships Carrying Dangerous Bulk Chemicals.

Annex III: MARPOL Annex III entered into force on 1 July 1992. It contains general requirements for packaging, labeling, labeling, documentation, loading, decontamination, splitting and notification standards for the prevention of pollution by harmful substances. The Annex complies with the procedures described in detail in the International Maritime Dangerous Goods (IMDG) Code, which has been extended to marine pollutants. The amendments entered into force on 1 January 1991. (Barnea, 2014)

Annex IV: Marpol Annex IV entered into force on 27 September 2003. It introduces requirements for the control of marine pollution from sewage from ships. ***Annex V.*** This Annex contains regulations for the prevention of pollution from ship - based waste and entered into force on 31 December 1988. It specifies the distances from land to which materials can be disposed of and subdivides different types of rubbish and marine debris. The requirements are much stricter for some "special areas", but perhaps the most important part of the Annex is the complete ban on dumping plastics in the ocean (Parsons & Allen, 2018).

Annex VI*:* MARPOL Annex VI entered into force on 19 May 2005. It introduces regulation of air pollution from ships, including emissions of ozone-depleting substances, nitrogen oxides (NOx), sulfur oxides (SOx), volatile organic compounds and the incineration of ships. It also sets requirements for waste reception facilities for offshore platforms and drilling rigs and for the creation of SOx emission control sites (Barnea, 2014).

The MARPOL International Convention has been amended several times, most notably the amendments concerning the control and maintenance of ozone-depleting substances, the mandatory change of oil fuel in relation to the procedures for ships entering or leaving SECA areas and FO limits for sulfur, by encouraging the creation of a ship-based waste management plan and by a general ban on dumping any rubbish in the ocean, with the exception of food waste, cargo residues, washing water and animal carcasses. There are other provisions that describe when and how to dispose of acceptable waste.

2.1.3. The International MLC Convention.

The Maritime Labor Contract (Maritime Labor Convention - MLC) ¨ is the no. 186 International Labor Organization Convention, established in 2006 and incorporating all modern standards of existing international conventions and recommendations for maritime work, as well as the fundamental principles contained in other international labor conventions (Litinskaya, 2016). The contracts apply to all ships entering the ports of the Contracting Member States.

The convention entered into force on 20 August 2013, one year after 30 ratifications were registered by countries representing more than 33% of world shipping. Already after five ratifications, the ratifying countries (Bahamas, Norway, Liberia, Marshall Islands and Panama) accounted for 43% of total world shipping. Since September 2018, the convention has been ratified by 88 countries representing over 93% of global shipping. Although the Convention has not been ratified worldwide, it has far-reaching implications as vessels from non-signatory States attempting to enter the ports of signatory states may face penalties for non-compliance with the MLC. The contract consists of sixteen articles containing general provisions as well as the code.

Title 1: Minimum requirements for seafarers to work on a ship

Title 2: Terms of employment

Title 3: Accommodation, leisure facilities, food and catering

Title 4: Health protection, medical care, welfare and social security protection

Title 5: Compliance and enforcement

There are general regulations for each title, which are further set out in the mandatory standards as well as in the contract guidelines. Guidelines are generally a form of implementing a regulation according to the requirements, but states are free to have different implementing measures. Regulations and standards must in principle be fully implemented, but a country can implement a "substantially equivalent" regulation, which it must declare when ratifying it. Some sailors criticize the contract, saying that it does not address real issues and important needs for maritime navigation, such as decent-sized cabins and adequate rest hours, including the fact that the contract guidelines were ratified without their participation (Lavelle)

2.2. International Security Management Code (ISM)

The International Safety Management Code (ISM) is an international standard for the safe management and operation of ships at sea. The main purpose of the ISM code is to ensure safety at sea and to prevent damage to property, personnel and the environment. In order to comply with the ISM Code, the company operating the vessel must first be inspected by submitting the SafSafety Management System (SMS) προς manual to the competent authorities of the country whose flag the ship is flying. . Once a company is audited, a "Document of Compliance (DOC)" is issued, which is valid for 5 years. With the issuance of the DOC to the Company, each vessel can be inspected to verify the vessel's compliance with the ISM code.

The SMS manual consists of the following elements:

- Commitment from the top management.
- A Handbook of Supreme Political Commitment.
- A procedure manual that records what happens on the ship, both during normal operations and in emergencies.
- Procedures for conducting internal and external inspections to ensure that the ship is performing operations as documented in the operations manual.
- The identification of a person on land as a liaison between ships and land personnel and to verify the application of SMS
  A system for identifying practices that do not correspond to those documented for the purpose of performing corrective actions.
- Regular evaluations of the management.

In addition, the ship must be maintained in accordance with the provisions of the relevant rules and regulations and in accordance with additional requirements that may be determined by the company. The observations of the inspector or the control body of the ship are incorporated in the SMS from the headquarters of the company. The requirements of the ISM Code can be applied to all merchant ships over 500 GT. The ISM code is a chapter of SOLAS, while where SOLAS does not apply the ISM is not mandatory. Compliance with the ISM Code is sometimes required by the vessel's customer, regardless of its G Gross Tonnage (GT).. The ISM Code was created by IMO and Chief Ferriby Marine Captain Graham Botterill, Special Adviser to the House of Lords on Ship Safety.

On the evening of March 6, 1987, the Herald of Free Enterprise, carrying more than 450 passengers, about 80 crewmembers, more than 80 cars and about 50 trucks, left the Belgian port of Zeebrugge for the English port of Dover. Shortly after, the Herald of Free Enterprise passed through the Zeebrugge reparation; water flooded the bilges of the ferry and destabilized it, causing it to sink within minutes. A total of 193 lives were lost in this accident.

The main cause of the accident was that the vehicle and passenger boarding platform remained open, allowing a large inflow of water as the boat increased its speed as the person responsible for closing the platform slept in his cabin. The judicial investigation revealed that the negligence of this person was just the last of a long series of actions that laid the foundations for a major accident. The investigation identified the weaknesses of both the master of the ship and his crew, as well as the competent authorities in terms of the coast and the way they managed the accident (Jyrkinen, 2005). The report summarizes the management's attitude towards security in the following statement: "From top to bottom the corporate body was infected with the disease of elasticity" (Sheen, 1987).

"Herald of Free Enterprise" was a modern ship equipped with advanced technology systems and manned by a highly specialized crew. Just seven years before the accident, it was built at a German shipyard in accordance with international maritime safety regulations. The general frustration in the shipping industry following the sinking of the "Herald of Free Enterprise" was typical of the type of accident and it was it that initiated the process of drafting a maritime safety management treaty that eventually led to the development of the code ISM.

2.3. The effect of the ISM code on Shipping

Given the level of accidents on ships, people and the catastrophic consequences for the environment, the ISM has established rules for matters relating to the organization of shipping operations related to safety and the general protection of the environment, resulting in the introduction of an international standard for safe operation and management of ships.

As a result, the minimum requirements were introduced through which a system for the safe management and quality of shipping was imposed, which focuses on the management methods of the senior management of the shipping company, as well as the imposition of a close information on safety measures, as result of the distinction and division of responsibilities and handling for both ship and onshore personnel (Tzannatos & Kokotos, 2009).

Prerequisite and perhaps most basic of all, in order for the implementation of ISM to be effective, is the existence of a deep belief on the part of the company that the benefits of implementing such a system contribute to the establishment and development of another culture for maritime safety. The main goal of the correct implementation of the ISM is to minimize accidents in shipping so that losses in personnel and material are eliminated and the transport of cargo at sea is carried out safely and reliably. Measures and proper information and training of staff have been instrumental in achieving this goal. In addition, it introduced measures taken by shipping companies to improve ship maintenance,

Following the introduction and final implementation of the ISM, the competitiveness of shipping companies increased, mainly due to the prestige it gave them. In general, in terms of international trade, certification from the implementation of the ISM Code is now considered a mandatory and necessary document for the charter of ships as it is required by charterers, port authorities and insurance companies.

Professor Theotokas (Theotokas, 2011) states that the benefits that emerge from the implementation of ISM include: a sense of responsibility from the crews and employees, commitment from the top of the company, prevention, frequent communication between ships and offices based on mutual respect and the establishment of trust by employees but also by the company in general of the general importance of security management.

In addition, the implementation of the ISM, drastically reduces the cost of the business as there is an improvement in a number of parameters, such as safe cargo transportation, efficiency, productivity improvement, achieving better premium prices, trust among staff, the reduction of pollution requirements as well as the change in the way safety is generally treated, which in turn has led to improved staff handling (Tzannatos & Kokotos, 2009).

However, in recent years and always in relation to what used to be the case, what makes most shipping companies comply with the requirements of the ISM Code, is the obligation to follow the regulations established by the various Government, Transnational and International Organizations. It has now become clear that compliance with ISM rules has the effect of increasing the profits of shipping companies by creating a healthy competitiveness and a secure business environment. Shipping companies now support the ISM as its implementation brings financial benefits to them both in the medium and long term.

In addition, the implementation of the ISM has improved two-way communication and cooperation between ship and onshore personnel due to modern information and communication systems, resulting in better work coordination (Strandet et al., 2017). Through the ISM application, new useful tools have been introduced for the communication and exchange of information on various aspects of security from the company's onboard ship and vice versa. Coordination, co-operation and operation of crews on board have also been improved, and safety meetings have been established on a regular basis. Furthermore, the fact that the information is disseminated to all ships of the company's fleet results in the creation of a database,

The responsibilities and roles of the crew both on board and on land have been distributed and clarified through the implementation of the ISM, due to the standard system documents of the system, which results in a better awareness of the crew's duties. In particular, the fragmentation of responsibilities for emergencies has been clarified and described through specific ISM articles. Another important event from the implementation of ISM, is the greatly improved corporate responsibility for safety and environmental issues.

Although it is generally accepted that at this stage the ISM does not have significant shortcomings and there is no need to change or modify it, one of the main disadvantages of implementing the ISM is the increase in bureaucracy, Small shipping companies that do not have sufficient administrative staff face difficulties in implementing the code as in many cases a different specialized manager is required for each individual responsibility of the management in matters related to the environment. Therefore, small businesses will have to increase their administrative costs, but thus lose their competitive advantage. Conversely, the larger the size of a shipping company, the lower the cost per ship of the company, as the company usually has a large number of qualified individuals who are able to take on the individual responsibilities of the ISM requirements. It is therefore clear that the burden of operating costs on each ship mainly affects small businesses.

Another disadvantage is the burden on staff with unnecessary formal reporting procedures that are often considered by companies to be too time consuming, complicated and cumbersome (Pum et al., 2002), while at the same time they consider that the security management system has become extremely complicated. . Many maritime safety advocates consider it necessary to simplify the documentation of the safety management system. A simplified and improved process will not only mean a reduction in costs, but also translates into a system upgrade that may be used more rationally.

Practical examples of successful implementations of the ISM Code should be available, while best safety management practices by shipping companies should be disseminated throughout the shipping industry, and public administration should provide in any case required. interpretations of the requirements of the Code, in order to avoid misunderstandings and undertaking work on ships that may not need to be done (Lappalainen, Kuronen, & Tapaninen, 2012).

3. Case Study - Annual budget of operating expenses of a ship

3.1. Accounting in Shipping

Shipping accounting and costing of a shipping company are objects of the maritime economy and even more objects of the maritime micro-economy. The objectives of shipping accounting should not differ from general accounting practices. Therefore, determining, monitoring and controlling the financial condition of a shipping company, measuring ship costs, and partial and aggregate results are one of the main objectives of shipping accounting.

The accounting system, freely chosen by the company in the context of generally accepted accounting methods, is the inventory, the single entry and the double entry. The only suitable method in the current economic conditions of business activity is the double entry method.

The presentation of the accounting facts, ie the accounting analysis of the financial operations is carried out in accounting books kept for this purpose. The importance of books for any business is twofold, that is, internal and external. With modern accounting techniques it is easy to develop multiple calendars, per type of accounting function, simultaneous information calendars and general or detailed calendars, automatic balance sheet and P & L, Cash Flow statements etc.

There are no major differences in the type and extent of accounts kept in shipping accounting compared to other areas of accounting. The differences are determined by the specificity of certain transactions of the shipping company. The technique of these transactions together with the administration and management of shipping companies constitute a special sector of the shipping economy. The main and most common accounts, as they appear in a shipping company but not limited to, are:

- Ships capital expenses
- Charterers/Voyage expenses
- Class and Responsible Organizations
- Agent fees (Disbursement accounts)
- Crew
- Contracts/Block fees
- Insurance
- Supplies - Ship Suppliers
- Maintenance and repairs (R&M)
- Bunkering-Lubricants

- Annual and special survey
- Repairs - Shipyards
- Master general account (MGA)

3.1.1. Operating Income Accounting

The ship is used for various purposes, such as entertainment (eg cruise ships), science (eg research vessels), economic reasons (eg submarine cables) and profit (eg merchant shipping) and other purposes. The most common use is for financial purposes and mainly for profit. Today, the use of the ship to achieve financial benefits (profit) is of the utmost importance. The use of the ship for profit purposes, ie commercial employment, can be done either by the owner or by a third party.

However, in terms of financial interest, the biggest focus is on the transportation of goods and people. In order to proceed, the charterer draws up a contract between the carrier, who may be the owner or operator, and the other party, the charterer, in respect of the chartered ship in full or in part for shipping (shipping contracts) or for the carriage of goods by sea (freight contracts) or passengers (passenger contracts). This obligation is undertaken in exchange for a load.

Various criteria are used to be included in the charter categories. According to these criteria, shipping practice has defined the following types of fares:

- Charter agreements based on the commercial operation of the ship,
- Discrimination charter agreements based on ship tonnage.

3.1.2. Fare Clearance and Goods Supply Contracts

As already mentioned, cargo is the financial benefit of the carrier for the shipping services offered. In all forms of chartering, there are two main participants, ie the parties, the charterer and the carrier. The complex circumstances, together with the need for a suitable organization in order to provide specialized services to both parties, created the need for a charter broker (intermediary). If the commission entitled to the broker is paid at the time of signing the charter agreement or at the time the goods are loaded on board, then the commission is calculated on the basis of the cargo corresponding to the weight or volume of the cargo at the charter party.

Before referring to the accounting of fares and commissions, it is necessary to enter a picture of liquidation bonds and commissions in charter contracts by capacity.

Example Case:

CENTROCON charter vessel for 8,000 tonnes of grain from Baiha Blanca to Yokohama.

- Removal: £ 225 € per day
- Shipping: £ 112, 5 per day
- Fare £ 3, 50 per ton of delivered cargo
- Delivery of 8,354 tons of grain

Clearing of fares and contracts for the supply of goods

- Load 8,354 tons x £ 3.50 £ 29,239
- Plus: Demurrage 4 days x £ 225 £ 900
- Total £ 30,139
- Minus: Supply for charterers
- Address Commission 3% x 30,139 £ 904
- Brokerage 1% x 30,139 £ 301
- Total £ 1,205
- Net Load £ 28,934

Charter contracts based on tonnage include many terms of a legal and financial nature and this is of particular interest to the shipping company's accounting. Charter by capacity, in addition to the waiting time at the port, requires some time for loading and unloading. Loading and unloading times are specified in the charter party and are attributed to the term.

Laycan is defined as the maximum time available for chartering to complete the loading and unloading of the ship. The charterer is obliged to load and unload the vessel within the respective times specified by the fare. The start time of the delay time requires:

- Arrival of the ship at the agreed point (port, dock)
- Ship notice of readiness for loading or unloading
- Charter alert etc.

Within the time period specified by the delay time, the loading and unloading of the ship must be completed. The fare can provide only one loading and unloading time, ie it does not separate the time between loading and unloading. Unique time is characterized by the term reversible delay time. The loading and unloading times are added together to indicate the total loading and unloading time. Thus, after the end time of the loading location there is a time for unloading. This means that if the loading time is exhausted, then there is the unloading time of the ship, which is called setback. In other words, the time that has elapsed without the loading or unloading being completed is considered demurrage.

3.1.3. Voyage Start and End Time

Of great accounting importance is the determination of the start and end time of a trip. It is understood that the journey ends with the unloading and delivery of cargo to the beneficiaries. It is known and occurs during the signing of the charter contract and when the ship for which the charter contract has been signed remains at sea or in port.

Under the charter contract, the shipowner is responsible for bringing the ship to the port of shipment. This voyage to the port of cargo is called a preliminary voyage. The beginning of the preliminary journey coincides with what is called the beginning of the journey. Thus, the owner has the first obligation to bring the ship to the port of loading with due diligence and maximum shipment (earned time). The fare sets a deadline, the last day of which is considered as the cancellation date. The owner is obliged to transport the ship to the port of loading, even if early arrival is not provided, as during the period of the charter contract.

It should be emphasized that neither party to the charter party has the right to terminate the charter contract unless there is a breach by the other party. Special cargoes may be agreed upon for a preliminary voyage, such as for a voyage from the port of unloading to the port of terminal.

3.1.4. Annual Charter Contracts

In maritime practice, the charter contract depends on the ship's destination structure and the place of delivery and return, and is provided in the following forms:

- Travel time charter
- Travel timing charter
- Time period charter

In the aforementioned charter agreements with time, the charterer undertakes the commercial employment of the ship and therefore pays the travel expenses of the vessel, in addition to the rent. while the shipowner bears the fixed costs (operating costs) of the ship, but also the cost of capital.

In internationally recognized and existing charters, the differences are not significant, in addition, there is a wide variety of them. The most important clauses of a time charter contract are as follows:

- The date and place of signing the time charter,
- Full name and registered office of shipowners and charterers,
- Full description of the boat (name, tonnage, etc.)
- The time charter period,
- Commercial employment limits, which refer to the regions of the planet that
- ships may travel as well as excluded areas,
- The cargo that the ship can carry and excluding cargo,
- The conditions of the ship, which refer to the airworthiness of the ship,

- The benefits of the carrier to the crew, supplies and maintenance of the ship,
- The benefits of the charterer, if the ship is leased which must deliver the ship's guidelines and employment, refuel the ship and pay the port costs,
- The time and place of delivery of the ship and the return,
- Fuel reserves, which the charterer must pay upon delivery of the ship, while the same applies to the owner upon return of the ship at agreed prices or at internationally prevailing prices
- Rent and other financial issues,
- Cancellation of rent payment (out of rent), which describes the reasons why the time charterer is not obliged to pay rent,
- Commissions and brokerage fees, where the respective amounts and beneficiaries are determined,
- The terms of the general average, discrepancies, exceptions, arbitration,
- of real estate, war, strikes, ice, etc.

3.1.5. Cancellation of Rent Payment

At the time charter, the time charterer is responsible for paying the rent throughout the term of the contract. Regarding the time of payment and the frequency of lease, in the time charter contract the lease is paid in advance, unlike the charter contract with capacity. Usually, referring to the charter contract, the amount of the rent is due for the current fifteen days or more by agreement, before or after them. The Time Charterer is responsible, during the time charter, for the equipment and payment:

- Ship fuel,
- Port costs, such as navigation, consular and other costs,
- The cost of using the trailer
- The cost of delivery to ports and return of the ship,
- Commissions and remuneration of agents working on behalf of ships, etc.

It is not always easy to distinguish between a freight charter and a freight contract. In this regard, the capacity-based charter contract must always be documented, and linked to the charter, while for freight contracts the charter must be exchanged for a landing account or a document documenting receipt. for loading.

3.1.6. Passengers and Transport

The number of passenger ships, including passenger cargo, does not exceed 5% of the total number of merchant ships worldwide. and capacity (gross tonnes) does not exceed 3% of world capacity. The limited number of passenger ships is mainly due to the competition of the plane, which attracts more passengers every day. At the same time, the management of travel agencies with inclusive excursions with a single payment, which in addition to transportation offer other services, such as the hotel, increase passenger traffic.

However, despite the limited size of maritime passenger transport worldwide, the revenues of shipping companies that own passenger ships, cargo ships and cruise ships will have to be addressed. The routes of a passenger and passenger cargo during a time period can be carried out either on domestic or international routes and there are regular routes or emergency routes. It is noted that cruise ships operate on fixed cruises via domestic and international routes. Finally, it is important to note the following concepts:

- Passenger: any natural person on board, other than the master and other crew members, and
- Employed means all natural persons on board, regardless of age, including captain and other crew members.

3.2. Description of Economic Characteristics of a Ship

3.2.1. Cost depending on the type of ship

The ship's operating finances can be considered in different ways, depending on the type of trade and the way the ship is used. Although there is a great variety in the type and size of ships, they are all generally used in one of five main ways, namely as cruise ships, cruise ships, industrial transport, service ships or free ships. The first four of these categories can be classified as ships operated by the owners, while the last category consists mainly of chartered ships.

Line Ships: Examples of this category are container vessels and car ferries. Because these ships provide a specific type of service, they sail on scheduled dates to carry passengers at scheduled times and depart whether they are fully loaded or not, resulting in a high cost of performing such a service. Fares and ticket prices must be set in such a way as to achieve satisfactory performance over a period of time relative to expected demand.

Cruise ships: The first cruises were offered by liner companies that used their liners either in their regular service or on special itineraries. These cruises were usually organized at a time of year when the numbers of passengers on regular ship services were likely to be low.

With the decline of passenger services caused by the increase in air travel, cruise ships ceased to be available for use and cruise ships began to appear. These ships are designed as floating hotels or resorts, and the cruise business is now one of the fastest growing shipping businesses. Typically, cruise ships make trips that can last a week or two, travel even at night, and are designed with passengers on board that allow them to go ashore to see the sights of an area. Although every cruise is a scheduled service,

Industrial transport: Some large companies with significant shipping requirements either for the import of their raw materials or for the export of their final products or for both, have a number of ships to cover at least a basic part of their mission. Typical examples of such ships are tanker fleets owned by oil companies. ships specially designed to carry iron ore and / or coal owned by steel companies and ships designed to carry cars belonging to large car manufacturing companies.

The owners of these ships generally assume full responsibility for all aspects of the cost when the ship is used for the owner's commercial activities. The purpose of such property is to minimize the cost of an overall industrial process, but the lack of flexibility that often characterizes these operators has sometimes been found to work in the opposite way, and this type of ownership has declined in recent years.

US anti-pollution laws have had a severe impact on some of the major oil companies who now refuse to market their product in US waters due to their current unlimited liability and instead receive service from traditional shipowners.

Service boats: Percentage of cargo ships carrying cargo and providing services to other ships or offshore facilities. Examples of service vessels are tugs, dredgers, navigation vessels, offshore safety vessels, etc. These services can be paid for directly, as in the case of tugs or indirectly through port charges or in some cases through taxation.

Free Ships: These ships can be used in different ways under different types of fares. Most bulk carriers and oil tankers, along with many small container vessels and tanks, operate as such vessels, making this method the method of employment of most ships.

3.2.2. Cost proportional to the use of the ship

An owner typically uses a ship in one of four ways: for his own commercial activity, in other commercial activities as a pilot, or in other commercial activities through time chartering or general chartering of the ship. In the case of ships used by their owner for their own commercial use, the owner generally assumes full responsibility for all aspects of the cost. Regarding the ships used by the owner as a pilot, an owner can determine the employment of the ship in various ways, such as:

- By concluding supply contracts for the movement of a large volume of cargo in regular shipments of a certain size, based on the fixed exchange rate per tonne transported
- Allowing the ship to be assigned to a charterer to carry a single cargo at a specified rate per tonne or
- Allowing the ship for a simple time charter trip for a set amount per day

Through bids and charters the owner can cover the cost of capital, operating costs and travel costs consisting of port charges and fuel receipts. The terms of the charter specify who pays the cargo handling costs as follows:

1. Wholesale terms (Gross) - Owner pays for loading and unloading
2. Free Shipping (FOB) - The charterer pays for the shipment
3. Free disembarkation (FD) - The charterer pays for the unloading
4. Free Entry and Exit (FIO) - Freighter pays for loading and unloading

Under the time charter of a simple trip the charterer is obliged to cover the travel costs and the handling costs of the cargo. In the case of free ships available for charter time, the shipowner undertakes to provide a ship for use by the charterer or at a specified time which may last from a few months to 20 years.

The charterer is responsible for determining the travel and cargo at charter and also to cover all travel expenses, including fuel, docking fees and cargo charges. The shipowner provides the ship and crew and is responsible for covering capital charges and daily running costs. The rent is paid only for the time the ship is in service and stops during a possible breakdown or repair. However, charges continue to apply in cases where the ship is delayed in port or sails empty for reasons not due to the ship.

In the case of a free ship for charter, the charterer provides the crew and is responsible for the maintenance of the ship, with the shipowner only having the responsibility of providing the ship and meeting the cost of capital. In practice the charterer uses the ship as if in his possession.

3.2.3. Description of financial criteria for shipping investment

There are a number of different financial criteria that can be used to determine the potential success of a shipping investment or to compare the benefits of alternatives. These criteria should be taken into account:

- The value of investing in time
- The full life of the investment
- The changes in terms of income and expenses expected at the time of the investment
- The financial data of the time of investment such as interest rate, taxes, loans and investments

The present value of the investment represents the fact that an amount of money that is available at a given time has much more value than the same amount that will be available after a certain number of years. In addition, interest is a key factor in calculating whether there is a need for borrowing or not. Interest can be simple or complex and its description is based on the following relationships:

- Simple interest
  - Total repayment after N years: $F = P (1 + N * i)$
- Complex interest
  - Total repayment after N years: $F = P (1 + i) N$
  - In this case the factor $(1 + i) N$ is called the complex amount factor (CA), and P = initial investment.

The reverse of CA is called the present value factor (PW) of the ship, which is described by the following relationships:

$$PW = 1 / (CA) = (1 + i) -N$$

$$P = (PW) F$$

The present value of the amount F containing all the accumulated interest is the same as the present amount P. If the loan is repaid in annual installments of capital in addition to the interest, this can take two forms:

- Equal repayment of capital in installments, with interest paid to the reduced account or

- Equal annual installments with interest prevailing in the first years and with capital repayments in the following years.

The concept of equal annual payments gives the ability to convert a current amount of money into a sum of annual payments over a specific number of years with the total sum of years A being linked to the amount invested and the current sum P being the capital recovery factor (CRF)

$$A = (CRF) P \text{ and}$$

The inverse (CRF) is the present value factor (SPW). This is the multiplier required to convert a number of regular annual payments to a present amount. To find the annual amount (A) that accumulates to provide a future amount (F), this is multiplied by the amortization rate (SF)

The inverse of (SF) is the Serial Quantity Coefficient (SCA)

Net present values (NPVs) of income and expense are calculated based on the expected life of the ships (N) years. The final amount should be positive for the investment to be profitable at the expected discount rate - or when alternatives are being compared it should be the larger amount.

The required transfer fare (RFR) is the one that will produce zero NPV, ie the limit value rate. The metaphor of the above equation gives:

The interest rate must be taken into account in the above calculations. If the charge is known or at least can be assumed, the interest rate at which money can be borrowed with NPV = 0 can become the criterion. It may be worth noting that the financial forecasts of the kind described in the preceding paragraphs are made at constant monetary values. Inflation and the consequent decrease in future monetary value together with changes in exchange rates are not included in these calculations, although both need to be estimated and taken into account in more detailed forecasts.

Capital costs are included in the costing of all the different modes of operation of the ship and are in fact the only cost element for chartering the ship. Includes capital expenditures:

- Loan repayment
- Loan interest
- Profit
- Taxes

The interest on the loans and the repayment of the loan can be taken together as capital amortization. Most of the capital requirements are the repayment of the loan used to pay the yard. Shipyard payments are almost always made in several installments during the construction period with one last installment at the end of the warranty period (usually one year after delivery).

Before the ship starts to win, its total cost will have risen above the bid price due to interest payments on the amounts paid along with other costs arising from the construction supervision, the hiring of the crew and the provision of supplies. of owners and initial supplies. In addition, it is an excellent contract that does not involve additional payments for changes in specifications during construction.

An obvious way to minimize capital burdens is to keep the cost of capital low, which can be achieved with good buying in relation to shipbuilding prices. The initial construction cost may, in principle, remain low with the construction at a lower level, although if this means that the ship will have a shorter duration than normal, this may not be cost effective. When considering capital economy measures, care must be taken that any lower standards adopted do not lead to higher operating costs which would negate any savings.

The second largest component of the capital charges is the amount paid on the interest of the borrowed money to cover the construction costs of the ship and its start-up. So another way - and probably one of the most important ways - in the long run - to minimize capital burdens is to get the most interest rates available.

Finally, at the end of any useful life the economic cost is calculated, the ship will still have value, even if it is just scrap metal, and an adjustment will have to be made to estimate the cost of depreciation. The general assumption made in most economic estimates is that the ships will have a service life of 20 years. While many continue to serve for much longer periods, others end up obsolete much earlier, or as a result of changes in technology and / or business standards a period of 20 years is probably a reasonable compromise.

The profit that the shipowner intends to make together with the taxes that will result from this profit is the second part of the capital requirements.

Although depreciation is not included in operating cost calculations, it seems appropriate to include a short paragraph at this point, as it has a very significant impact on shipping companies' accounts, taxes paid and profits made in specific years. Depreciation is the process of writing off the cost of capital in company accounts. There are two classic methods of dealing with depreciation, namely:

i. Linear Impairment. Assuming a lifespan of 20 years, the depreciation will be 5% per annum.

ii. Reduced depreciation of the balance. Assuming it is estimated at 15% per year. In this case we have:

- 1st Year: 15% x 100 = 15%
- 2nd Year: 15% x (100-15) = 12.75%
- 3rd Year: 15% x (100-15-12.75) = 10.84%
- 10th Year: 3.52%
- 20th Year: 0.94%

In most countries there are special provisions for dealing with shipping depreciation in terms of taxation. These treatments vary from country to country, as do taxes. Most of these treatments allow the cost of a ship to be written off at a much faster rate than conventional treatments. It is generally in the interest of a shipowner to amortize as quickly as profits allow and thus reduce or at least defer tax payments. Although the book value of a ship at all times will be its initial cost plus the cost of any repairs or alterations and less accumulated depreciation, the value of a ship, as measured by its potential sale price, is likely to change dramatically during lifetime.

3.3. Daily operating expenses

The daily operating costs of a ship include the following:

- Crew costs
- Supplies and storage
- Maintenance and repairs

- Insurance
- Management and overhead

These costs are added to the charter calculations and, of course, also apply to charter trips and the owner's operation. These are the costs that arise whether the ship is at sea or in port.

3.3.1. Crew costs

The two main factors that determine the cost of the crew today are the number of crew and the nationality of the various divisions of officers and crew. The effect of numbers is offset to some extent by the fact that a smaller crew generally tends to have more "leaders" and fewer "lower ranks" and the fact that all members of a reduced crew should (or certainly should) have a higher level of training. and therefore more (or should) be paid per employee. The automation and higher quality materials required to reduce supervision and maintenance, thus allowing the reduced crew to operate the ship satisfactorily, will increase the cost of capital,

3.3.2. Supplies and storage

Supplies are usually purchased locally at the ship's commercial ports and the annual cost is calculated per person per day. Ships consume an excellent variety and a fairly large amount from various stores with the three most important items being handmade, paints, chemicals and gases, but with smaller amounts spent on items such as freshwater, clothing and the stationery. Lubricating oil is sometimes included in this item, but is usually included in the cost of receiving fuel.

3.3.3. Maintenance and repair

With today's small crews, offshore maintenance is necessarily limited, but careful planning by the ship's staff during their stay at sea can significantly speed up the work done when it arrives at port and minimize costs. An item under this heading is dry dock maintenance, but this is no longer an annual event with three or even five-year intervals becoming commonplace. Maintenance budgets generally include amounts for hull and superstructure work, cargo areas and systems, main and auxiliary machinery, electrical installation and safety equipment plus research costs.

3.3.4. Insurance

The insurance can be divided into own loss insurance (Hull & Machinery) and shipowner liability insurance (P&I). The cost of Hull & Machinery insurance is directly related to the cost of the ship's capital, with the management company's insurance history having a minor effect. Costs have risen sharply in recent years due to the number of major accidents and aging in general. The policies now provide for more deductible quantities and in case of legal requirement the operating costs can be significantly increased. P&I insurance covers shipowners' liability for cargo, crew, pollution, potential collisions and passengers. P & Premiums

3.3.5. Management and overhead

Administration costs are a contribution to the shipping costs of a shipping company or to the fees paid to a management company plus a non-negligible amount for communications etc, along with flag fees. Among the items included in the general charges may be the cost of renting items of ship equipment, such as a radio installation, which are sometimes hired instead of purchased as part of the ship.

The rental fee can be reduced by making a massive multi-boat deal with one company. The decision between purchase and lease requires reconsideration from time to time as prices, interest rates and tax measures change. At present, the use of leased equipment is declining. It is also advisable to take into account an amount of exceptional data when preparing a cost estimate, as unfortunately very often there will be something that cannot be predicted.

3.4. Voyage costs

The voyage expenses of a ship include the following:

- Fuel loading
- The port
- Towing and navigation
- Various port costs

These elements are added when there is a move from a time charter to a trip charter calculation and of course apply to the owner function.

3.4.1. Bunkering costs

Bunkering costs depend on the type of fuel. So we have the following cases:

Heavy fuel oil: Factors affecting the cost of petroleum fuels are distance traveled, average power used, specific fuel consumption and cost per tonne of fuel. The first of these can be minimized by good navigation, which must also take into account favorable and negative currents. The latter can be minimized by moving at such a slow speed that it will allow the required schedule to be met. maintaining the hull finish at a high level of smoothness (a task that is much easier than in the past with the last long lives and self-polishing antifouling paints). and at an earlier stage, with good design of the ship and propeller lines.

Specific fuel consumption can be minimized at the design stage by a good choice of engines and at the operating stage keeping the engine well maintained. Fuel costs can be minimized by carefully selecting the supply port, although any cost savings achieved in this way must first cover any additional costs if diversion is required or there is a reduction in cargo capacity or an increase in average displacement. travel that increases power and consumption. Fuel costs can also be reduced by using poorer fuel quality, although any savings should be assessed against any additional cleaning costs, etc. required for fuel use and any increases in maintenance and repair costs that may result from its use. The mass market is another way to achieve an advantageous price.

Diesel fuel: Here the factors involved are the number of days, as the generators remain in operation both in port and at sea and the average electric charge. Because the cost of diesel is much higher than that of diesel fuel, it is advantageous to meet as much electrical load as possible by using shaft-driven generators.

Lubricating oil: Although the amount of lubricating oil consumed is relatively small, the high unit cost results in a significant cost. This item is sometimes included in storage, but as usage depends on the distance traveled, it looks best grouped by refueling.

3.4.2. Port fees and navigation fees

Port charges and channel usage fees: These depend on the tonnage of the vessel and the trading plan. Small mixed and / or net quantities are particularly important on some routes, such as those used by the Suez or Panama Canals.

Navigation costs: Navigation costs are usually also estimated at gross tonnage, but can be reduced in some transactions by having an officer with a navigation certificate where this procedure is followed.

Towing and mooring costs: Towing charges can be eliminated or reduced if the ship is equipped with an arc propeller or approved high-performance steering equipment. Anchoring time can be reduced by installing special decking equipment, such as a self-aligning winch.

3.4.3. Cargo management costs

Cargo management costs include the costs of both loading and discharging the cargo together with any claims that may arise on the cargo. Cargo handling costs are excluded from the cost of chartering the voyage but must be borne by the shipowner. Cargo handling time can be reduced along with the cost of this function, by providing good load handling features such as:

- Large hatches that give good access,
- Ship doors, where appropriate.
- Hatch covers that can be opened and closed quickly.
- Lifting vehicles with forklift for stacking speed
- Drilling cranes or cranes on the ship with lift capacity Optimized for the transported cargo and fast cycle time.
- Self-loading facilities.

When trade is based on a small number of specific ports, there is an alternative to minimizing ship costs and using coastal cargo handling. Cargo packing or palletizing can significantly change the time and cost of cargo handling.

4. Ways to reduce costs Through design and operation optimization.

There are two methods of approaching optimization problems. The first method is the "Direct Search Method", through which solutions are created by changing parameters either systematically at certain stages or randomly. The best of these solutions are then taken as the estimated optimal. However, systematic change soon becomes prohibitively time consuming as the number of changing variables increases. Random searches are used instead, but these are still insufficient for problems with many design variables.

The second method is the "Steep Slope Method", in which solutions are created using some information about the local slope (in different directions) of the function to be optimized. When the steep slope in all directions is (almost) zero, the estimate for the optimal is established. This approach is more effective in many cases. However, if there are enough local optimals, the method will "stick" to the nearest local optimum instead of finding the universally optimal, i.e. the best of all possible solutions. Discontinuities (steps) are problematic, and even functions that change abruptly in one direction but very little in the other make this approach slow and often unreliable.

Most ship design optimization methods are based on steep approaches because they are very effective for smooth functions. For example, the cost function varies with respect to length L and commitment factor CB (Figure 1). A gradient approach method will quickly find the lowest point of the cost function if the function K = f (CB, L) has only a minimum, which is often the case.

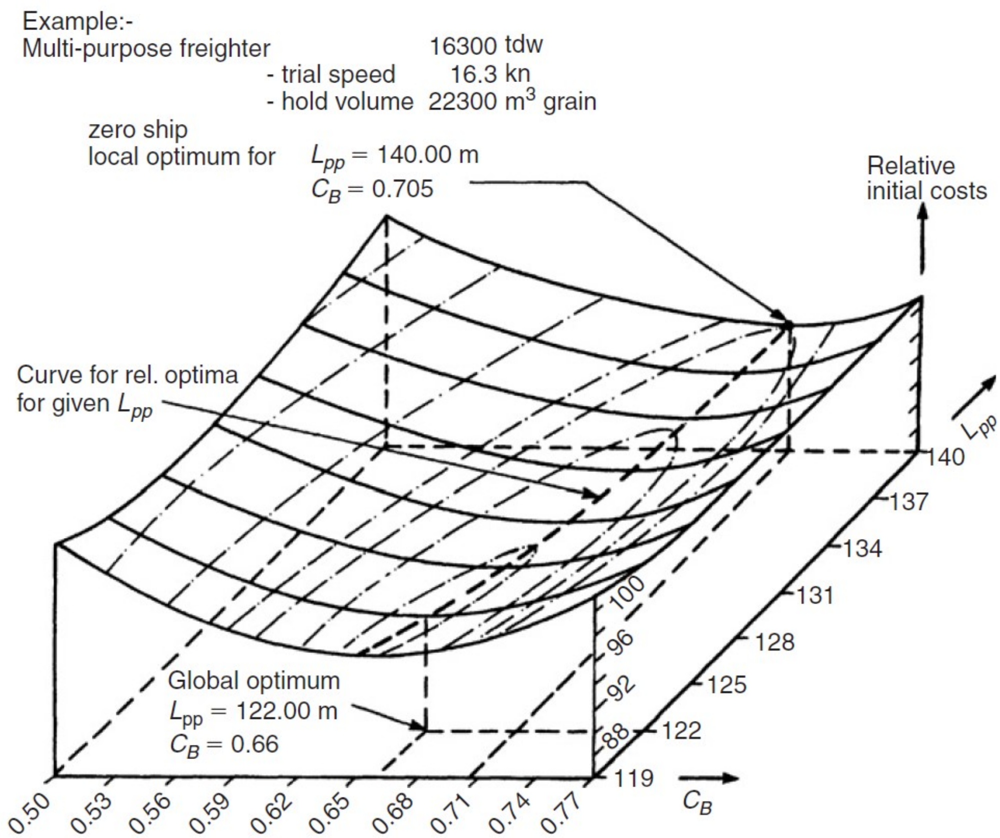

Figure 1: example of total cost depending on length and commitment factor

Repeating the optimization with different starting points can bypass the problem of "gluing" to a local optim. One option is to combine both approaches with a quick instant search using a few points to determine the starting point of the steep approach. Repeated alternation of both methods - with the direct approach using a smaller grid scale and range of variation at a time - has also been proposed. A realistic approach to dealing with discontinuities (steps) first presupposes a continuous function and then repeats the optimization with the lower and subsequent upper values as constant constraints and gets the best of the two optimals thus obtained. Although, in theory,

The goal of optimization is the objective function or criterion of optimization. It is subject to limit conditions or restrictions. Constraints can be expressed as equations or inequalities. All technical and economic relationships to be considered in the optimization model must be known and expressed as functions. Some relationships will be precise, e.g. others will be approximate, like all empirical formulas, e.g. in terms of resistance or weight estimates. The procedures must be sufficiently precise, however they must not be consumed too long or require very detailed information. Ideally all variants should be evaluated by the same procedures. If a change of procedure is necessary, for example,

A problem that is often encountered in optimization is the need to use unknown or uncertain values, e.g. future prices. Realistic assumptions must be made. When these assumptions are extremely uncertain, optimization for several assumptions is common ("sensitivity study"). If a variation in some input values only slightly affects the result, they can be obtained rather arbitrarily. The main difficulty in most optimization problems does not lie in the mathematics or methods involved, i.e. whether one particular algorithm is more efficient or powerful than others, but in formulating the goal and all the constraints. If the person is not clear about his goal, the computer can not perform the optimization. The designer must first decide what he really wants. This is not easy for complex problems. Often the designer will list many goals that a design will achieve. This is then referred to in the literature as "multi-criteria optimization", e.g. Sen (1992), Ray and Sha (1994). The expression is nonsense if taken literally. Optimization is only possible for one criterion, e.g. it is foolish to ask for the best and cheapest solution. The best solution will not come cheap, the cheapest solution will not be so good. There are two main ways to tackle "multiple criteria" problems that lead to optimizing a single criterion: Sen (1992), Ray and Sha (1994). The expression is nonsense if taken literally. Optimization is only possible for one criterion, e.g. it is foolish to ask for the best and cheapest solution. The best solution will not come cheap, the cheapest solution will not be so good. There are two main ways to tackle "multiple criteria" problems that lead to optimizing a single criterion: Sen (1992), Ray and Sha (1994). The expression is nonsense if taken literally. Optimization is only possible for one criterion, e.g. it is foolish to ask for the best and cheapest solution. The best solution will not come cheap, the cheapest solution will not be so good. There are two main ways to tackle "multiple criteria" problems that lead to optimizing a single criterion:

- One criterion is selected and the other criteria are expressed as constraints.
- A weighted sum of all the criteria is the optimization goal. This abstract criterion can be interpreted as an "optimal compromise".

However, the rather arbitrary choice of weight factors makes the optimization model vague and we prefer the first option. During optimization, design requirements (constraints), e.g. the weight of the load, the dead weight, the speed and the holding capacity, must be satisfied. The starting point is called the "base design" or "zero variant". The optimization process produces alternatives or variations different, for example, in main dimensions, form parameters, displacement, main propulsion force, capacity, fuel consumption and initial cost.

Constraints usually affect the result of optimization. Figure 2, for example, shows the effects of the various optimization constraints on the section curve.

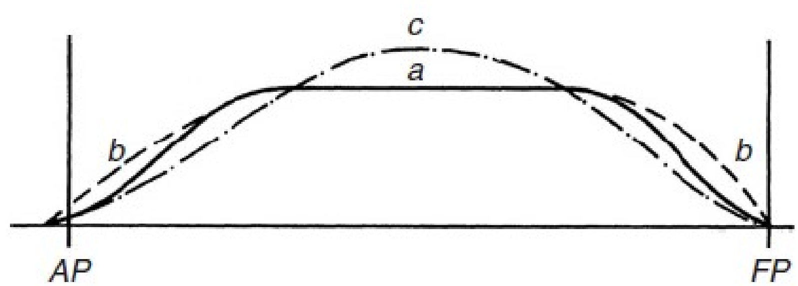

Figure 2. Variations generated in a section curve in each section with different optimization constraints: (a) the basic form, (b) a more complete form with more displacement - optimization of the capacity with maximum principal dimensions and variable displacement, (c) a thinner form with the displacement of the base from form a, with variable main dimensions.

Optimized main dimensions often differ from the values available on built ships. There are several reasons for these discrepancies. One of them is that some of the already built ships are not optimal. In these cases, the standard design process is based on statistics and comparisons with existing ships, rather than detailed approaches and formal optimization. The designs found thus meet the requirements of the owner, but there may be better solutions for both the yard and the owner. Technological developments, changes in legislation and economic factors (eg fuel price) are immediately reflected in an appropriate optimization model, but not when based on partially outdated experience. Modern design approaches are incorporating more and more design analytics and comparing more computer-generated variations. This should reduce the differences between optimization and structured ships.

Another case of differentiation of optimized main dimensions from the prices available on built ships, is that the optimization model is considered insufficient. The optimization model may have neglected factors that are nevertheless important in practice, but are difficult to quantify in an optimization process, e.g. sea conservation behavior, flexibility, vibration characteristics, easy handling of cargo. Even for directly integrated quantities, important relationships are often overlooked, leading to optimal error. This can be observed in cases where:

- A faster ship usually attracts more cargo, or may charge higher fares, but revenue is often considered independent of speed.
- A larger ship will typically have lower freight costs per unit of cargo, but cargo handling time at port may be increased. Port time is often considered independent of size.
- In ships with refrigerators, the design of the cooling holder in terms of insulation and temperature requirements affects the optimal main dimensions. Additional investment and annual costs must be included in the model to achieve realistic results.
- A ship's performance often deteriorates over time. Operating costs will increase accordingly, Malone et al (1980), but are usually obtained over time.

The economic model can use an inappropriate objective function. There is often confusion about the treatment of depreciation. This is not an expense item, ie a cash flow, but an accounting and tax calculation method. The optimization model can also be based on very simplified technical relationships. Most of the practical difficulties are in obtaining realistic data that should be included in the analysis, rather than in the engineering of the analysis. For example, the procedures for weight estimation, power forecasting, and manufacturing cost are quite inaccurate, which becomes apparent when comparing the results of different published types.

The result of the optimization model should be compared with the built ships. Consistent differences can help identify important factors that have been neglected so far in the model. A sensitivity analysis of the underlying types of assessment will provide a bandwidth of the "optimal" solutions and any project within this bandwidth should be considered equivalent. If the bandwidth is too large, the optimization is negligible.

A critical view of the optimization results is recommended. But proper optimization can lead us to better designs than just traditional designs. The main dimensions of the ship should be properly selected by a nautical architect who understands the relationships of the various variables and the pitfalls of optimization. An automatic optimization does not absolve the designer of his responsibility. It only supports him in his decisions.

In reference to the cost of materials as cited by Jan O. Fischer & Gerd Holbach (2011) «At the beginning of the design and construction phase of the shipbuilding, the use of materials and working hours are quantified and distributed, based on the cost of the shipyard and the organizational structure of the company. This starts at the highest level, and as the degree of detail of the ship's design increases, the programming improves accordingly and is implemented at the level of the individual components. » (p. 22) It is therefore important to evaluate the cost up to the final stage of construction.

4.2. Implementation of optimization in ship design

Typical line optimization, including bulbous bow, even for fixed main dimensions, is beyond our current computing capabilities. Although such a formal optimization has been attempted using CFD methods, the results were not convincing despite the high computational effort, Janson (1997). Instead, we will focus here on ship design optimization problems involving only a few (less than 10) independent variables and rather simple functions. A typical application would be to optimize the main dimensions. However, optimization can be applied to a wide variety of ship design problems, ranging from fleet optimization to structural design details.

In fleet optimization, the goal is often to find the optimal number of ships, speed and tonnage of ships without analyzing the main dimensions, etc. The economic efficiency of the ship usually improves with increasing size, as the specific cost (cost per unit load, eg per TEU or per tonne of load) for initial cost, fuel, crew, etc., is reduced. However, size restrictions limit size. The draft (and therefore indirectly the depth) is limited by canals and ports. However, for sinking limitations it must be borne in mind that a ship is not always fully loaded and ports can be excavated to greater depths during the life of the ship. The width of the tankers is limited by the construction and repair docks. The width of container vessels is limited by the width of the container decks. Locks restrict all dimensions of indoor boats. In addition, there are less obvious aspects that limit the optimal ship size:

1. Limited cargo availability combined with certain departures frequency expectations limit size on some routes.

2. Port time increases with size, reducing the number of trips per year and therefore income.

3. The shipping company is losing flexibility. Several small ships can more often serve different routes / ports and thus will usually attract more cargo. It is also easier to respond to seasonal fluctuations.

4. Increase of port fees with the quantity. A large ship calling at multiple ports may need to pay more port charges than several smaller ships serving the same ports on different routes, thus calling at fewer ports.

5. On container shipping lines, shipping companies offer door-to-door transportation. The cost of catering and inland increases if the large ships serve only a few ports and distribute the cargo from there to the customer. The cost of handling cargo and land transportation often exceeds transportation cost savings.

These estimates largely concern shipping companies to optimize ship size. The factors that favor the largest size of the ship are, (Buxton, 1976):

- Increased annual load flow.
- Faster load management.
- Load is only available in one way.
- Long-term cargo availability.
- Longer travel distance.
- Reduced freight costs and costing.
- Predicted port improvements.
- Reduced cost of shipbuilding unit.
- Reduced service frequency.

After determining the optimal size, speed and number of ships along with some other specifications, the design engineer at the yard is usually instructed to optimize the main dimensions as a design principle. Further design steps will include local boat shape, e.g. the design of the bulbous arc lines, the structural design, etc. The optimization of the structural elements often includes only a few variables and rather precise functions. Söding (1977) presents as an example the weight optimization of a corrugated bolme. Similar examples are found in the studies of Liu et al (1981) and Winkle and Baird (1985).

A pioneering work on optimizing the design of a ship was carried out by the Aachen Technical University in Germany (Schneekluth, 1967; Malzahn et al, 1978). Such optimization changes the technical aspects and evaluates the result from an economic point of view. Fundamental equations (eg), technical specifications / constraints, and equations that describe the economic criteria are a more or less complex system of conjugated equations, which usually include nonlinearities. Gudenschwager (1988) gives an extensive optimization model for Ro-Ro ships with 57 unknowns, 44 equations and 34 constraints.

To create such complex design models, it is advisable to start with a few relationships and design variables and then improve the model step by step, always comparing the results with the designer's experience and understanding the changes from the previous, simpler model. . This is necessary in a complex design model to avoid errors or inaccuracies that cannot be clarified or that may even go unnoticed without the application of this step-by-step procedure. Design variables that include step functions (number of propeller blades, power of installed engines, number of containers the width of a ship, etc.).

Weakly dependent on change variables or variables of secondary importance (eg displacement, deck volume, stability) should only be introduced at a later stage of the development process. The most economical solution is often located within the limits of the search space defined by restrictions, e.g. the maximum allowable draft or width of Panamax for large ships. If this is done in the first cycles, the relevant variables must be fixed in the optimization model in other cycles. Keane et al. (1991) discuss in more detail the solution strategies of optimization problems. Simplifications can be maintained if the relative error is small enough. They can also be examined later.

4.3. Basic Financial Elements of Optimization

4.3.1. Prepaid Payments

A summary of the economic criteria has been presented in the past. For optimization purposes, all payments are discounted, ie converted taking into account the interest, until the boat is put into operation. The interest rate used for the discount is usually the market rate for long-term loans. The discount reduces the value of future payments and increases the value of past payments. The individual payments that are discounted are, for example, the installments for the new construction cost and the resale price or the collection price of the ship.

For an 8% interest rate, the PWF is 0.2145 for a 20 year investment life and 0.9259 for a 1 year. If the collection value of a ship after 20 years is 5% of the original cost, the discounted value is about 1%. Thus, the error when neglecting it for simplification is relatively small.

CRF is the capital recovery rate. The shorter the investment life, the higher the CRF with the same interest rate. For an 8% interest rate, the CRF is 0.1018 for 20 years and 1.08 for 1 year of investment life. The above types require the payment of interest at the end of each year. This is the rule in financial calculations. However, other payment cycles can easily be converted to this rule. For example, for quarterly payments, divide i by 4 and multiply N by 4 in the above formulas.

For expenditures incurred at longer intervals than years or on a particularly irregular basis, e.g. large-scale repair work, an annual average is used. When cost changes are expected, future costs should be introduced at the average annual level as expected. The cost estimate is based on current prices, which can be adjusted if there are recognizable long-term trends. The problems are:

1. The useful life of the ship can only be estimated.

2. During the useful life, costs can change resulting in cost items changing in absolute terms and relative to each other. After the oil crisis of 1973, for example, fuel costs increased dramatically.

Thus, all the costs and revenue of a ship can be reduced to a total "net present value" (NPV). Only cash flows (expenses and income) should be taken into account, not expenses used only for accounting purposes. Yield is the interest rate i that gives zero NPV for a given cash flow. Yield is also called an overpriced cash flow rate or internal rate of return. It allows comparisons between widely different alternatives that also differ in the invested capital. In principle, performance should be used as an economic criterion for evaluating various ship alternatives, as it is mainly used in business management as a benchmark for investments of all kinds. Lifespan should be the same for different investments. Unfortunately, Performance depends on uncertain quantities such as future fares, future operating costs and the life of a ship. It also requires the highest computational effort, as construction costs, operating costs and revenue must be estimated.

Other economic criteria that take into account the time value of money include NPV, NPV / investment or Required Transfer Load (_ the load giving zero NPV), and are discussed in more detail by Buxton (1972, 1976). The literature is full of long and rather academic discussions about what is the best criterion. However, the choice of economic criterion is of secondary importance due to possible errors in the optimization model, such as the violation of important factors or the use of inaccurate relationships.

Discounts reduce the impact of future payments. The initial cost, without discount, represents the single most important payment and is the least affected by uncertainty. (Individual installments of the initial cost will have to be repaid, but these will be made during the short period of construction of the ship.) The "initial cost" criterion simplifies the optimization model, as many variables independent of variation can be omitted.

Initial costs are often recommended as the best yardstick for the yard, as this maximizes the yard's profit. This only applies if the price for various alternatives is stable. However, in modern business practice, the yard must convince the shipowner of its design. The price will then be correlated with the expected cash flow. In short, the optimization criterion should usually be performance. For a simpler approach, which can often suffice or serve to develop the optimization model, the initial cost can be minimized.

4.3.2. Construction cost optimization

Construction costs can be classified into:

- Labor cost
- Cost of materials
- Overhead cost

Overheads relate to individual ships in some appropriate way, for example on an equal footing with all ships built during the accounting period, depending on direct costs, etc. For optimization, production costs are divided into (Figure 3):

- Costs dependent on change
- Costs depending on the shape of the ship:
  - Cost of the hull
  - Promotional unit costs
  - Other costs that depend on the variation
- Cost independent of changes
- Costs that are the same for each variant

Buxton (1976) gives some simple empirical estimates for this cost. Construction costs are covered by equity and loans. The source of the capital can be ignored. Then interest on loans does not need to be taken into account in cash flow. The return on capital should then be higher than the alternative forms of investment, especially the interest rate on long-term loans. This approach is very simple for an investment decision, but it is enough to optimize the main dimensions.

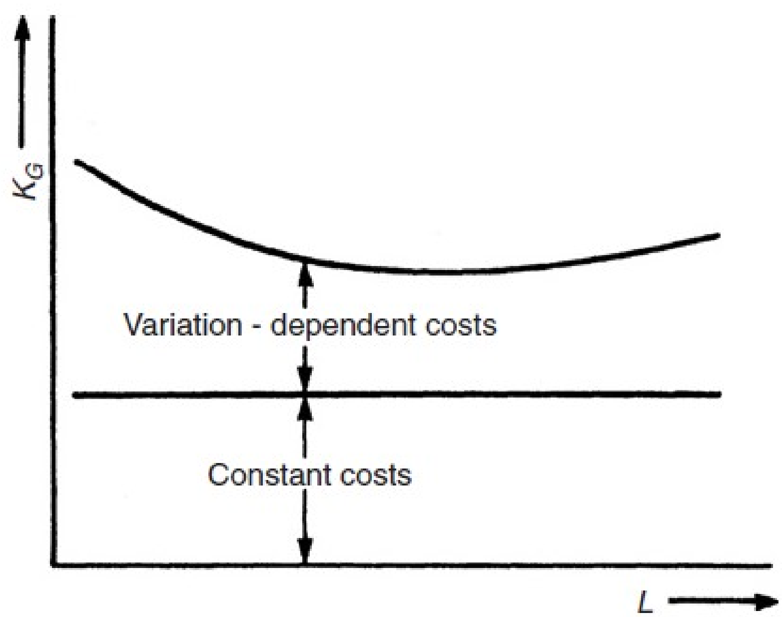

Figure 3. Distribution of costs according to the length and regardless of the length. Usually 15-45% of the initial cost is due to the yard, while the rest to external suppliers. The trend is to increase outsourcing. Of the shipyard's wages, 20% is usually available for design and 80% for production for a type of cargo ship, while warships typically account for 50%.

Superstructures and roofs are usually assumed to be independent of variation when considering variants of the main dimensions. The costs that depend on the variant are:

- Steel costs.
- The cost of a propulsion unit depends on the change.
- Equipment accessories

Shipyards usually determine the cost of processed steel in two separate groups. The cost of rolled steel, which is the cost of slabs and rolled parts, is determined separately using prices per tonne and other costs, which mainly represent wages. This cost group depends on the number of man-hours worked on the ship within the construction area. The numbers vary greatly, depending on the production methods and the complexity of the construction. As a gross estimate, 25-35 man-hours / tonne for container vessels are reported in the older literature. There are about 30-40% more man-hours / t required to build the superstructure and roofs than for the hull, and for the construction of the ends of the ship in comparison with the parallel middle body. The amount of work associated with the weight of steel is greater on smaller ships. For example, a ship with a capacity of 70,000 m 3 below deck volume needs 15% less construction time per ton than a ship with 20,000 m3 (Kerlen, 1985).

For optimization, it is more practical to formulate the unit cost per tonne of installed steel and then multiply that unit cost by the weight of the steel. This unit cost can be estimated as the estimated production cost of the steel hull divided by the net weight of steel. Kerlen (1985) gives the specific steel costs such as:

where k0 represents the production cost of a 140 meter long boat with CB = 0.65. The type is valid for ships with 0.5≤ CB ≤0.8 and 80 m ≤ L≤ 200 m. The type can be modified, depending on the cost of material and changes in the content of work.

To optimize the main dimensions, the cost of the propulsion unit can be considered to be constantly changing with the propulsion power. It can then be obtained by multiplying the propulsive power by the unit cost per unit of power. Another possibility is to use the catalog prices for engines, tools and other large factory components when calculating and considering other parts of the machine by multiplying by an empirical factor. Only parts that are functions of propulsion power should be considered. The electrical installation, which counts as part of the engine design - including generators, ballast water pipes, valves and pumps - is largely independent of variation.

Whether certain components depend on the variation depends on the type of ship. To optimize the initial cost, the equipment can be divided into three groups:

- Equipment independent of the variants, e.g. electronic units on board.
- Marginally dependent equipment from change, e.g. anchors, chains that can change if the classification number changes with the change. If the dependence on the change is not strong, this equipment may be omitted.
- Heavily dependent equipment on change, e.g. The cost of the lockers increases approximately in relation to the length of the lid and the 1.6 force of the width of the cover, ie the wide lockers are more expensive than the large, narrow ones.

Finally, the unit costs associated with steel weight and machine may change over time. However, if their ratio remains constant, the result of the calculation will remain unchanged. If, for example, a design calculation for a future application assumes the same growth rates compared to the present for all costs incurred in the calculation, the result will give the same major dimensions as a calculation using only current data.

4.3.3. Optimization of annual expenses

The income of cargo ships depends on the amount of cargo and fares. Both must be a function of speed in a free market. At the very least, interest on committed capital costs of cargo should be included as a lower estimate for speed dependence. Costs for the life of a ship include the cost of insuring the ship, where the annual cost of this category is usually 0.5% of the cost of production, repair and maintenance costs that are usually available to shipping companies, fuel costs and lubrication, which depends on engine performance and operating time, crew costs for which crew requirements depend on engine power but remain unchanged for a wide range of costs for the same system. So the cost of the crew is usually independent of the variation. If the optimization result shows a different crew requirement from the base ship, crew cost differences may be included in the model and the calculation repeated.

In addition, costs for the life of the ship include overheads (port costs, etc.), which are independent of variation for a fixed ship size, the cost of labor stocks and additional equipment, which depend on the size of the ship, the size of the engine factory, the number of the crew, etc. The dependence on variance is difficult to calculate, but the cost is small compared to the other types of costs mentioned. For this reason, differences in asset costs can be neglected.

Finally, the above costs include the cost of cargo management which is affected by the type of ship and cargo handling equipment both on board and on land. It is largely independent of variation for a fixed ship size. Taxes, interest on loans that cover the initial construction costs and inflation have only negligible effects on the optimization of the main dimensions and can be ignored.

4.3.4. Propulsion unit cost optimization

Standard propulsion unit components, such as motors, gears, etc., introduce steps in the cost curves. The stepped curve may have a minimal point at the wing or at the bottom of a fracture. With the initial cost, the optimum is always at the beginning of the curve to the right of the break. Switching from a smaller to a larger engine reduces engine load and therefore reduces repair costs. Fuel costs also change step by step as the number of cylinders changes. On one side of the break point, the smaller engine is largely fully loaded. On the other hand, the engine with one more cylinder has reduced charge, ie lower fuel consumption. So,

The assumption of constant speed when the propulsive power changes in steps is only an assumption for comparison when determining the optimal principal dimensions. In practice, if the propulsion unit is not fully used, a higher speed is adopted.

4.3.5. Reduce operating costs by minimizing life cycle costs

In addition to purchase costs, life cycle costs also include operating and maintenance costs. If these costs are high after manufacture, the manufacturer must take these factors into account and give priority to minimizing the overall life cycle cost of the product. Higher production costs are acceptable if the total life cycle cost is ultimately lower. However, in order to achieve a competitive advantage, the cycle cost calculation must be performed thoroughly and the customer must not base his decision solely on the construction cost without taking into account these lower life cycle costs. Since ships generally have high operating costs and a long service life, life cycle cost analysis is particularly important. Operating expenses can generally be classified into traffic-related costs, such as fuel, and non-traffic-related costs, such as crew salary costs. The structure of these costs depends to a large extent on the type of ship and the way it is chartered. Time factors can also affect operating costs. For example, fuel prices increased significantly between 1970 and 1990, when the share of operating costs depends on a variety of very different parameters and can vary considerably, an analysis of operating costs should be the first step when one tries to minimize life cycle costs. Based on this analysis, project management can make decisions about the original design and engineering of the ship. A typical example of technical alternatives where minimizing production costs does not automatically lead to a reduction in life cycle costs is the propulsion system, which not only affects production costs but also substantially affects fuel consumption. Another example is the ship's maneuverability, where the additional cost of additional flexibility aids, such as a bow thruster, must be weighed against the resulting reduced cost of the need for tugs. The importance that shipowners attach to life cycle costs in relation to shipbuilding price seems inconsistent. The following are observed: which not only affects production costs but also substantially affects fuel consumption. Another example is the ship's maneuverability, where the additional cost of additional flexibility aids, such as a bow thruster, must be weighed against the resulting reduced cost of the need for tugs. The importance that shipowners attach to life cycle costs in relation to shipbuilding price seems inconsistent. The following are observed: which not only affects production costs but also substantially affects fuel consumption. Another example is the ship's maneuverability, where the additional cost of additional flexibility aids, such as a bow thruster, must be weighed against the resulting reduced cost of the need for tugs. The importance that shipowners attach to life cycle costs in relation to shipbuilding price seems inconsistent. The following are observed: The importance that shipowners attach to life cycle costs in relation to shipbuilding price seems inconsistent. The following are observed: The importance that shipowners attach to life cycle costs in relation to shipbuilding price seems inconsistent. The following are observed:

- The sale price is significantly more important than the operating costs.-The customer requires specific calculations of the life cycle cost from the manufacturer.-The responsibility for the necessary services in relation to the operation of the ship (eg maintenance) is ex entirely in the hands of the manufacturers and compensation for this is included in the sale price. This development is particularly prevalent for naval vessels.

The measures taken by manufacturers to predict and influence the life cycle cost of ships are also very different. However, in most cases, the full potential is not fully exploited by the systematic handling of uncertainties that are inextricably linked to projected life-cycle cost forecasts.

4.3.6. Efficiency of purchases / supplies

Maintenance is an activity that must be based on a Planned Maintenance System (PMS) plan. Scheduled maintenance makes it possible to predict costs and a fairly consistent budget can be prepared. If the ship's crews faithfully follow the PMS implementation on board, no theoretically unexpected change in maintenance costs is expected. The equipment and external human resources required for the scheduled maintenance are predictable, if the company finds the right equipment and organizes the workshops at a reasonable price, there will be no surprise that will seriously affect the cost. The company must draw up a workable maintenance plan, execute it fully and establish a complete inspection, the cost will be reduced. Repair requirements increase in the event of equipment malfunction mainly due to lack of maintenance. Although not fully approved, many marine management experts believe that the cost of maintenance (Cm) causes the square of Cm (??) of repair and the cost of missed opportunities. The age of the ships is a critical factor that increases the likelihood of accidents. Procurement policy and the budget of consumables, spare parts and supplies play an important role in the company's expenses. Supply budgeting is a dangerous aspect of ship management. This has to do with the large number of transactions involved, depending on the many, individual, commissions that can be relatively inexpensive. Another key element is how they are purchased, ie the process adopted by the managers, including the degree of autonomy assigned to the ship, as well as the locations around the world where the ship is from time to time and deliveries are affected. It is clear that it is vital to have an efficient policy in place that references procurement and to operate. It is important to make sure that this process does not place too much workload. That is, it is vital that the shipowner or manager does not fall into the trap of "knowing everyone's value, but not their value." This does not mean that the price is insignificant - but buyers should be aware of the substitution possibilities of inferior products, the reliability of delivery, etc. It is unlikely that a 5% savings on a supply order would seem to be a great deal if a late delivery means the ship is delayed for a day - or the ship has to set sail without receiving the order. (Drewry, 2006). Purchasing and procurement is a complex issue and requires a systematic approach to meeting requirements.

The basic principles of procurement are related to the following issues:

- The staff of the procurement department must be sufficiently experienced and specialized.

- Company staff and ship crew should be able to provide accurate information to procurement staff.

- There should be a reliable system for monitoring the supply, ensuring that the right order, arrived at the right location, at the right time, as well as accompanied by the right invoice and payment.

Geography plays a crucial role in price.

- The actual product mix is very diverse.

- The staff of the procurement department deals with a wide range of suppliers.

- Supply requires a choice that satisfies both quality and price.

- Supplier reliability is important for an uninterrupted supply flow.

Traditionally, the image of most ship suppliers has focused solely on the negotiations and transactions between the shipowner (or manager) and a certain category of ship supplier. As a result, supplies have tended to become an "exclusive" part of the shipping company. However, this picture is changing. Supplies become "Less isolated" as they move within the broader supply estimates. The procurement process, of course, concerns the acquisition of items required by the ship, but now brings to the equation other "management" and "analytical" aspects, in addition to the pure purchasing process.

Supplies are actually related to maintenance and repair costs. For a complete study, a regression analysis between supply and maintenance and repair costs must be performed. However, maintenance and repair costs are variables that change based on the type, age, operating hours of the ship, the company's maintenance policy, repair quality, etc. Thus it is very difficult to perform a regression analysis between all these factors. Such a regression analysis could be performed for a company but not for general research. Another issue that hinders such an analysis is the non-transparent structure of the shipping company and this hinders the collection of key data for the analysis.

4.3.7. Fuzzy Logic application to select the optimal maintenance method

Fuzzy logic can be considered as an extension of mathematical logic, where logical propositions have no absolute values of truth or falsehood and provide non-rigid mechanisms for drawing conclusions 1

In a study by Asst. Prof. Dr. Ergün DEMİREL and Asst. Prof. Dr. Dinçer (BAYER Piri Reis University, A STUDY ON COST OPTIMIZATION IN THE SHIP MANAGEMENT) supported by a team of experts applies Fuzzy Logic in order to reduce costs in ship management. Procedures implemented through vague logic are often not easily divided into distinct parts and can be difficult to model with conventional mathematics or rule-based examples that require clear boundaries or decisions. Therefore, vague logic is valuable when the boundaries between sets of values are not strongly defined or there is a partial occurrence of an event (Klein, 2004).

[1]. University of Macedonia http://ai.uom.gr/Courses/AdvancedNeuralNetworks/Material/FuzzyLogic.pdf

In their study, key factors that affect the reduction of costs in the management of ships were investigated. The following were identified as the main factors:

M = Maintenance

P = Commission

R = Repair

Factors that directly affect the success of supply, maintenance and repair were also assessed. The following are defined as the factors (criteria) that will be weighed:

A: The experienced and specialized staff of the company is important to reduce costs.

B: A well-organized outsourcing is important to reduce costs

C: The geographical factor is important for cost reduction.

D: The attitude of the ship's crew is important to reduce costs.

The weight of each factor for each sector that is significant in reducing costs was studied. The scale used is between 1 and 5 (5 is the most important weight). The weights of each criterion for the areas to be assessed are set out in Table 1.

Factors	A	B	C	D	Total
Level of significance	4	3	2	2	11
Gravity	36%	27%	18%	18%	100%

Table 1: Weight of importance of each factor 2

The importance of each factor for each region (Selection) is reflected in Table 2. The scale used is between 0 and 1. The normalized score is derived from the following formula.

Normalized score = ½ (1-sum / total sum)

Factors / alternatives	M (Maintenance)	P (Supply)	R (Repair)
A (Staff)	0.8	0.9	0.8
B (Outsourcing)	0.9	0.6	0.9
C (Geography)	0.3	0.9	0.5
D Ship crew)	0.4	0.4	0.3
Sum	2.4	2.8	2.5
Normalized scores	29.5%	32.0%	34.5%

Table 2: Normalized scores 2

Having the normalized score of each factor, we can now multiply the score converted in Table 2 by gravity and find the new weighted result as shown in Table 3.

Factors / alternatives	Gravity	M (Maintenance)	P (Supply)	R (Repair)
A (Staff)	36%	0.27	0.32	0.29
B (Outsourcing)	27%	0.24	0.16	0.24
C (Geography)	18%	0.05	0.16	0.09
D Ship crew)	18%	0.07	0.07	0.05
Sum	100%	0.65	0.71	0.67
Weighted results		32%	35%	33%

Table 3: Weighted results 2

Comparing the results of Table 2 and Table 3 we can observe some shift in the optimal choice. In Table 2, option R (repair) is preferred over M (Maintenance) and P (Supply). However, when we include the weight of the importance of each factor, we conclude that the P (Supply) option is the most preferred alternative.

[2] (The Second Global Conference on Innovation in Marine Technology and the Future of Maritime Transportation, 24-25 October 2016, Bodrum, Muğla, TURKEY)

5.1 Required for the research

A set of data has been collected for this analysis concentrating on the type, age and crewing of the fleet, the maintenance practices and effectiveness of the practices. The goal of this research is to evaluate the correlation between the date in order to identify the correlations and the most effective practice per case.

5.2 Interview questionnaire

1. Shipping company name (only name of company will be mentioned in the reference list only, the company will not be to the published data).
2. Department: Technical/Purchasing/Other
3. Position: Manager/Superintendent/Assistant
4. Type of vessel: Gas/Tanker/Bulker/Container/RO-RO/RO-Pax-Cruise/ Yacht/Navy
5. Average fleet age in years: <5 / 5~10/ >10
6. Type of charter: Voyage/ Time charter/Other
7. Trading: Spot/Worldwide/Liner
8. Crew top 4 (Cpt, C/M, C/E, 2E): Greek/Eastern EU/Filipino/Other
9. Maintenance major machinery (M/E, D/G, Compressors, purifiers): preventive/condition based.
10. Supply Spares major machinery (M/E, D/G, Compressors, purifiers): Genuine/Mix GEN-OEM/OEM.
11. Do you Supply Spares major machinery (M/E, D/G, Compressors, purifiers): Regular order as per need/Bulk fleet order/ Block fee agreement.
12. Maintenance major machinery: By crew/ Workshop/ Both.
13. Maintenance aux machinery: preventive/condition based
14. Supply Spares aux machinery: Genuine/Mix GEN-OEM/OEM.
15. Do you Supply aux machinery: Regular order as per need/Bulk fleet order/ Block fee agreement.
16. Maintenance aux machinery: By crew/ Workshop/ Both.
17. Supply of spares: Per case/Batches/Batches at convenient ports only.
18. Supply of stores: As required/ Per 3-4 months/ At convenient ports only?
19. Are services for Radio and safety equipment performed: Per case/Block fee agreement.
20. Are Repair and Maintenance services performed: Per case/Block fee agreement.
21. Are Class/Flag/ISM services performed: Per case/Block fee agreement.
22. Dry docking location/Yard: Per case/Fleet Agreement/ Both
23. Are lubricants supplied: Per case any supplier/Per case one agreed supplier/Agreement supply?
24. Are paints supplied: Per case any supplier/Per case one agreed supplier/Agreement supply?
25. MARPOL Emissions compliance: Scrubber/VLSFO/MGO

26. BWTS: Electrolysis / UV / other / N/A
27. Major Machinery breakdown occurrence frequency per year per vessel: more than 4 / less than 4 and more than 1/ less than 1.
28. Aux. Machinery breakdown occurrence frequency per year per vessel: more than 4 / less than 4 and more than 1/ less than 1.
29. Yearly Spares and repairs/maintenance service cost (incl. class, radio/nav.aids/safety) per ship: < 350K $ / 350~500K / >500K

5.3 Research

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8. METHODOLOGY

8.1.Research aim-questions

Current research aims to present useful information about maintenance, service and general data of ship companies, as well as to identify dependencies between the mentioned parameters. The research questions are the following:

1) How are the maintenance parameters related each other?

2) Do the maintenance parameters differ between the general characteristics of ship companies?

3) How are the service parameters related each other?

4) Do the service parameters differ between the general characteristics of ship companies?

5) How are the maintenance parameters related with the service parameters?

8.2. Research design

A quantitative primary, descriptive and correlative research was performed in a non-experimental design, using a closed type questionnaire. This type of research was considered appropriate, as concepts of maintenance and service are measurable (Creswell, 2013). Furthermore, quantitative research is appropriate as aim of current research is to identify relationships and dependencies between variables (Fowler, 2014). The non-experimental design, is the appropriate design for current research as aim of study is simply to describe the ship companies and spot differences, without controlling for external factors (Salkind, 2010).

8.3. Sample

Sample of current research was conducted by 20 ship companies. Table 1 represents the name of companies. Most of participants that represented the ship companies, work in the technical department, having the position of Superintendent. The majority of ship companies of current research have tankers or bulkers, with the average fleet age to be more than 5 years and voyage or time charter, regarding the type of charter. Most of participants stated that their company have worldwide trading area, while the top 3 crew nationality to be the Hellenic, Eastern EU and Filipino.

Table 1: Name of ship companies

Name of ship company
CSM
Modion Maritime Management S.A.
Safe Marine Assurance Ltd

Aerio Shipmanagement Ld

NAVARONE S.A

Eletson

UOM

SINAR MAS LOUIS DEVOS MARITIME

Euronav

Maran Tankers

ASTRA SHIPMANAGEMENT INC.

M/maritime Corp.

Roxana Shipping

Berkeley yachting LTD

Technomar

Hellenic navy

Sea World Management & trading Inc

Sea Globe

Minerva Marine Inc

Mantinia

8.4. Questionnaire

The questionnaire was originally constructed by the researcher and includes 29 closed type questions and 3 sections. The 1st section refers to general information of ship companies and includes 8 questions. The 2nd section refers to maintenance and involves 10 questions while the 3rd refers to service and involves 11 questions. Table 2 represents sections, questions and possible answers.

Table 2: Sections, questions and possible answers

Sections	Questions	Possible answers
General data	1. Shipping company name:	-
	2. Department:	Technical/Purchasing/Other
	3. Position:	Manager/Superintendent/Assistant
	4. Type of vessel:	Gas/Tanker/Bulker/Container/RO-RO/RO-Pax-Cruise/ Yacht/Navy
	5. Average fleet age in years:	<5 / 5~10/ >10
	6. Type of charter:	Voyage/ Time charter/Other
	7. Trading:	Spot/Worldwide/Liner
	8. Crew top 4 (Cpt, C/M, C/E, 2E)	Greek/Eastern EU/Filipino/Other

Maintenance	9. Maintenance major machinery (M/E, D/G, Compressors, purifiers):	Preventive/condition based.
	10. Supply Spares major machinery (M/E, D/G, Compressors, purifiers):	Genuine/Mix GEN-OEM/OEM
	11. Do you Supply Spares major machinery (M/E, D/G, Compressors, purifiers):	Regular order as per need/Bulk fleet order/ Block fee agreement.
	12. Maintenance major machinery:	By crew/ Workshop/ Both.
	13. Maintenance aux machinery:	Preventive/condition based
	14. Supply Spares aux machinery:	Genuine/Mix GEN-OEM/OEM
	15. Do you Supply aux machinery:	Regular order as per need/Bulk fleet order/ Block fee agreement
	16. Maintenance aux machinery:	By crew/ Workshop/ Both
	17. Supply of spares:	Per case/Batches/Batches at convenient ports only
	18. Supply of stores:	As required/ Per 3-4 months/ At convenient ports only?
Service	19. Are services for Radio and safety equipment performed:	Per case/Block fee agreement
	20. Are Repair and Maintenance services performed:	Per case/Block fee agreement

21. Are Class/Flag/ISM services performed:	
22. Dry docking location/Yard:	Per case/Block fee agreement
23. Are lubricants supplied:	Per case/Fleet Agreement/ Both
24. Are paints supplied:	Per case any supplier/Per case one agreed supplier/Agreement supply? Per case any supplier/Per case one agreed supplier/Agreement supply?
25. MARPOL Emissions compliance:	Scrubber/VLSFO/MGO
26. BWTS:	Electrolysis / UV / other / N/A
27. Major Machinery breakdown occurrence frequency per year per vessel:	more than 4 / less than 4 and more than 1/ less than 1.
28. Aux. Machinery breakdown occurrence frequency per year per vessel:	more than 4 / less than 4 and more than 1/ less than 1.
29. Yearly Spares and repairs/maintenance service cost per ship:	< 350K $ / 350~500K / >500K

8.5.Data analysis

Data were coded in Microsoft Office Excel 2016 and analyzed in statistical software IBM SPSS 24. In the descriptive statistics, data were presented with percentages and frequencies. In the inferential statistics, the chi-square test was used because all variables of research are nominal. The null and alternative hypothesis are represented below:

Ho: The tested variables are independent (Null hypothesis)

H1: The tested variables are dependent (Alternative hypothesis).

Only the statistically significant dependencies were presented. In cases that the expected count cells which have value lower than 5 were more than 20% the Fisher exact test was used. Significance was set at 5%. Thus, null hypothesis was accepted if p-value≥0,05 and rejected when p-value<0,05 (Field, 2017).

8.6. Ethical issues

Researcher took into consideration all the necessary issues, related to the nature of research and the psychology of participants that participated in current research (BPS, 2014). In particular:

- ✓ Subject of current research was approved by the University of researcher
- ✓ Professor of the University of researcher supervised the research
- ✓ Participants were informed about the research aim, that their participation is anonymous, voluntary and that their answers will be used only for the research aims of study. It was stated that name of company will be mentioned in the reference list only and that the company will not be linked to the specific answers
- ✓ The right to withdraw from research was clarified, during the process or 1 week after.
- ✓ Participants signed a consent form, to confirm that they want to participate.
- ✓ Researcher gave his personal information to participants in case they want to communicate for any reason.

9. RESULTS

9.1. Descriptive Statistics

9.1.1. General data

In this chapter, it is represented the general features of participants of the current research. Below, Table 3 and Graphs from 1 to 7 indicate that 90,0% (N=18) have technical department, 5,0% (N=1) in purchasing, while 5,0% (N=1) chose the category “other”.

With regard to the position, 70,0% (N=14) consists of superintendents and 30% (N=6) of managers. As for the type of vessels, 45,0% (N=9) have tanker, 35,0% (N=7) bulker, 5,0% (N=1) container, 5,0% (N=1) gas, 5,0% (N=1) yacht and 5,0% (N=1) navy.

Also, 50,0% (N=10) answered that they are more than 10 years in fleet, 40,0% (N=8) 5-10 years and 10,0% (N=2) less than 5 years. Regarding the type of charter, 45,0% (N=9) have voyage charter, 40,0% (N=8) time charter, while 15,0% (N=3) declared “other”.

In terms of the trading area, 80,0% (N=16) claimed that the trades take place worldwide, 15,0% (N=3) in a spot and 5,0% (N=1) in a liner. Finally, as it comes to the crew nationality, 35,0% (N=7) have Hellenic crew, 20,0% (N=4) Eastern EU, 20,0% (N=4) Filipino, while 25,0% (N=5) answered “other”.

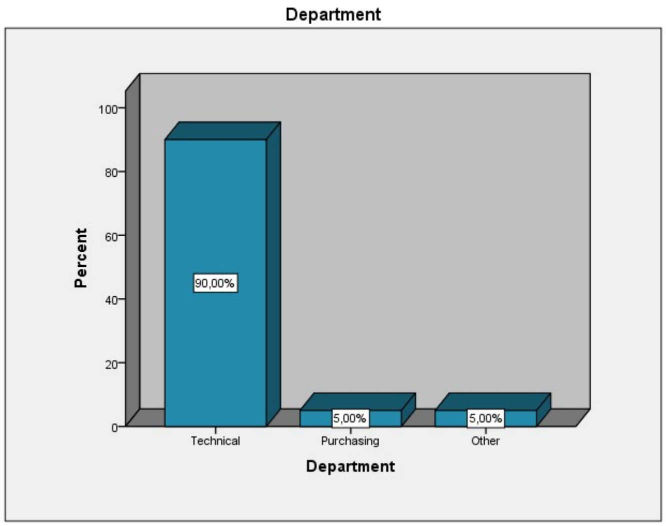
Table 3: General data

Characteristic	Category	N	f%
	Technical	18	90,0
Department	Purchasing	1	5,0
	Other	1	5,0
Position	Manager	6	30,0
	Superintendent	14	70,0
	Gas	1	5,0
	Tanker	9	45,0
Type of vessels	Bulker	7	35,0
	Container	1	5,0
	Yacht	1	5,0
	Navy	1	5,0
Average Fleet age in Years	<5	2	10,0
	5-10	8	40,0
	>10	10	50,0
Type of charter (mostly)	Voyage	9	45,0
	Time charter	8	40,0
	Other	3	15,0
Trading Area	Spot	3	15,0
	Worldwide	16	80,0

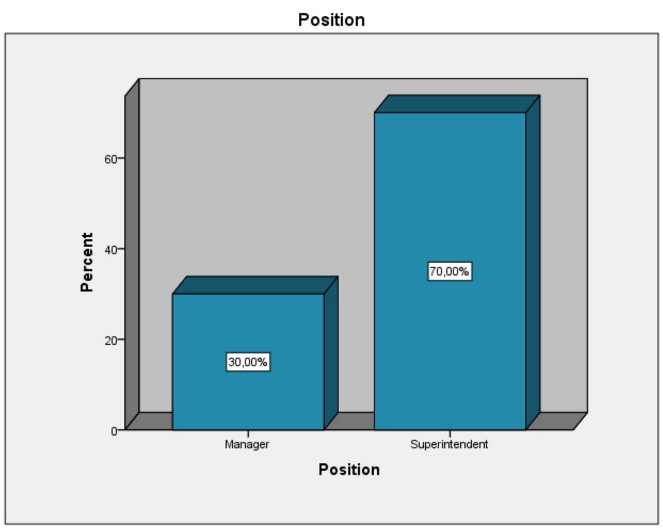
	Liner	1	5,0
	Hellenic	7	35,0
Top 4 Crew Nationality (Cpt. C/E, C/O, 2/E)	Eastern EU	4	20,0
	Filipino	4	20,0
	Other	5	25,0

N: Frequency

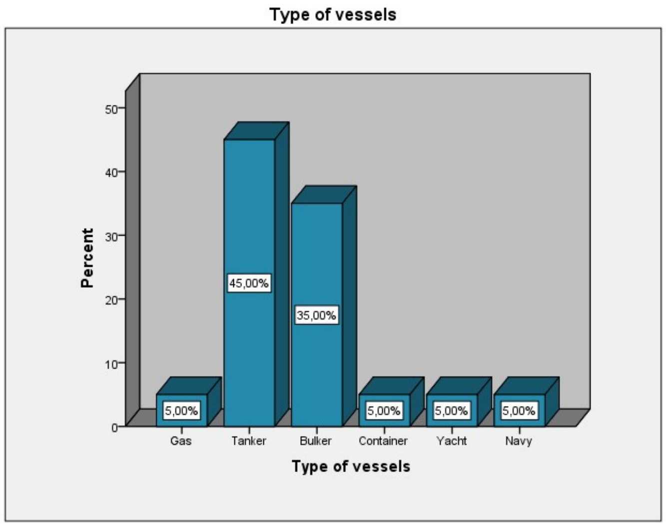
f %: Valid percent %



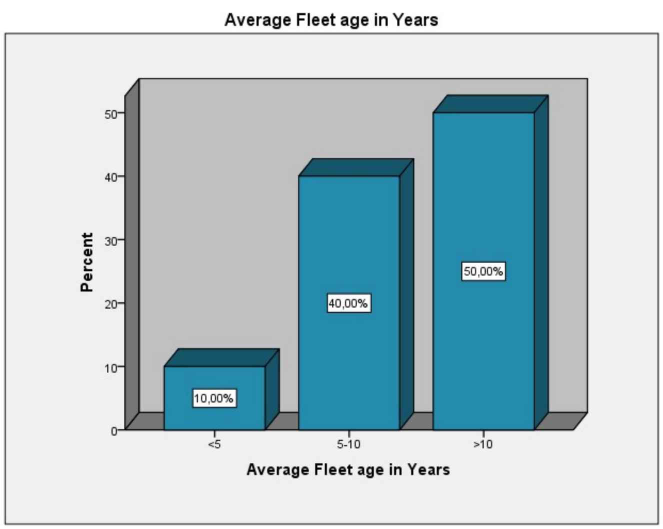
Graph 1: Department



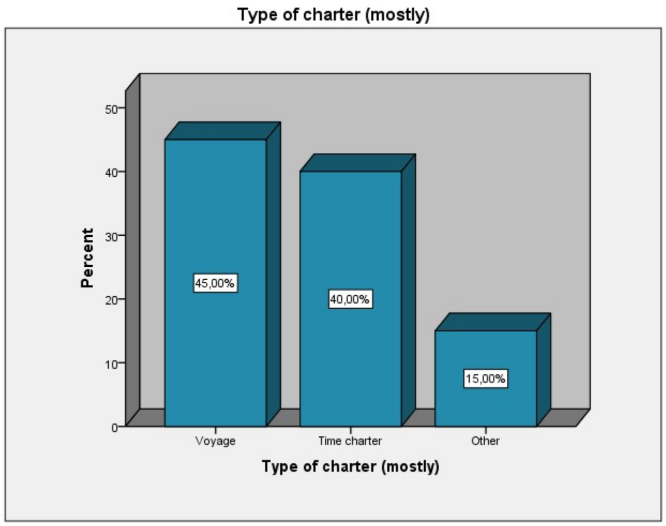
Graph 2: Position



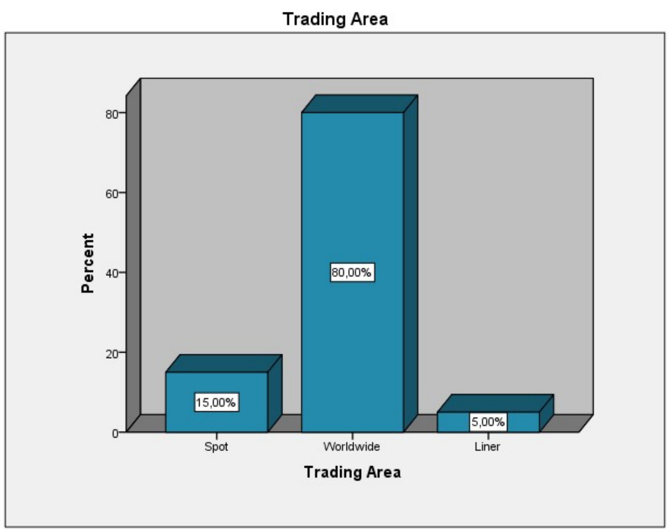
Graph 3: Type of vessels



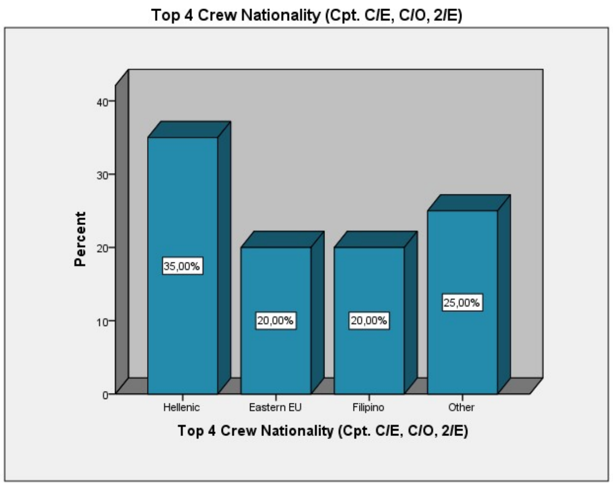
Graph 4: Average Fleet age in Years



Graph 5: Type of charter (mostly)



Graph 6: Trading Area



Graph 7: Top 4 Crew Nationality (Cpt. C/E, C/O, 2/E)

9.1.2. Major and Aux Machinery Maintenance

This chapter, constitute the general features that are related to the Major and Aux Machinery Maintenance. Below, Table 4 and Graphs from 8 to 17 indicate that 75,0% (N=15) have preventive maintenance major machinery, while 25,0% (N=5) have condition-based maintenance major machinery. The next question is multiple choice, which means that participants can choose more than one option. Thus, 100,00% (N=20) have genuine supply spares major machinery, while 60,00% (N=12) OEM. Moreover, 75,0% (N=15) supply spares major machinery (M/E, D/G, Compressors, purifiers) as needed, 15,0% (N=3) following bulk fleet order and 10,0% (N=2) following block fee agreement as per PMS.

In addition, 50,0% (N=10) claimed that the major machinery maintenance is carried out by the crew, 40,0% (N=8) by the crew and the workshop, while 10,0% (N=2) by both. Besides, 65,0% (N=13) answered that aux machinery maintenance is preventive and 35,0% (N=7) condition based.

The next question is multiple choice, which means that participants can select more than one response. Therefore, 90,00% (N=18) have genuine supply spares aux machinery, whereas 75,00% (N=15) OEM. Furthermore, 80,0% (N=16) supply aux machinery as needed, 10,0% (N=2) following bulk fleet order and 10,0% (N=2) block fee agreement. Into the bargain, 75,0% (N=15) indicated that maintenance aux machinery is performed by the crew, whereas 25,0% (N=5) by the crew and workshop. Further, 60,0% (N=12) stated that the forwarding of supply of spares is performed in batches at convenient ports, 25,0% (N=5) per case as needed and 15,0% (N=3) in bathes. Finally, 65,0% (N=13) asserted that the supply of stores is carried out per 3-4 months in convenient ports, 25,0% (N=5) as required, and 10,0% (N=2) at convenient ports only.

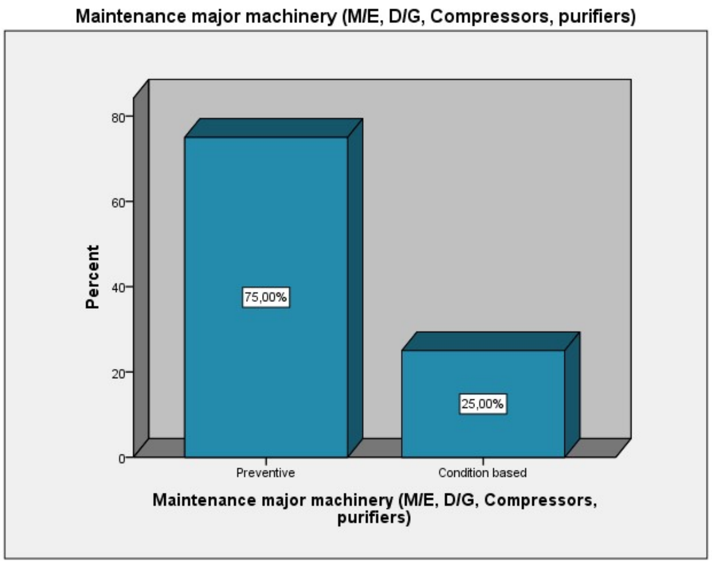
Table 4: Major and Aux Machinery Maintenance

Feature	Category	N	f%
Maintenance major machinery (M/E, D/G, Compressors, purifiers)	Preventive	15	75,0
	Condition based	5	25,0
Supply Spares major machinery (M/E, D/G, Compressors, purifiers):	Genuine	20	100,0
	OEM	12	60,0
Do you supply Spares major machinery (M/E, D/G, Compressors, purifiers)?	As needed	15	75,0
	Bulk fleet order	3	15,0
	Block fee agreement as per PMS	2	10,0
Major Machinery Maintenance	By crew	10	50,0
	Workshop	2	10,0
	Both	8	40,0
Aux machinery maintenance	Preventive	13	65,0
	Condition based	7	35,0
Supply Spares aux machinery	Genuine	18	90,0

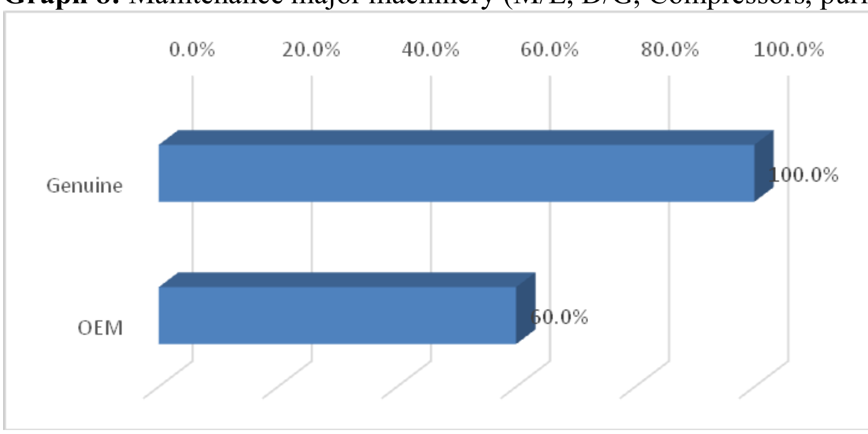
	OEM	15	75,0
Do you supply aux machinery?	As needed	16	80,0
	Bulk fleet order	2	10,0
	Block fee agreement	2	10,0
Maintenance aux machinery	By crew	15	75,0
	Both (Crew & Workshop)	5	25,0
Supply of spares (forwarding)	Per case as needed	5	25,0
	Batches	3	15,0
	Batches at convenient ports	12	60,0
Supply of stores	As required	5	25,0
	Per 3-4 months in convenient ports	13	65,0
	At convenient ports only	2	10,0

N: Frequency

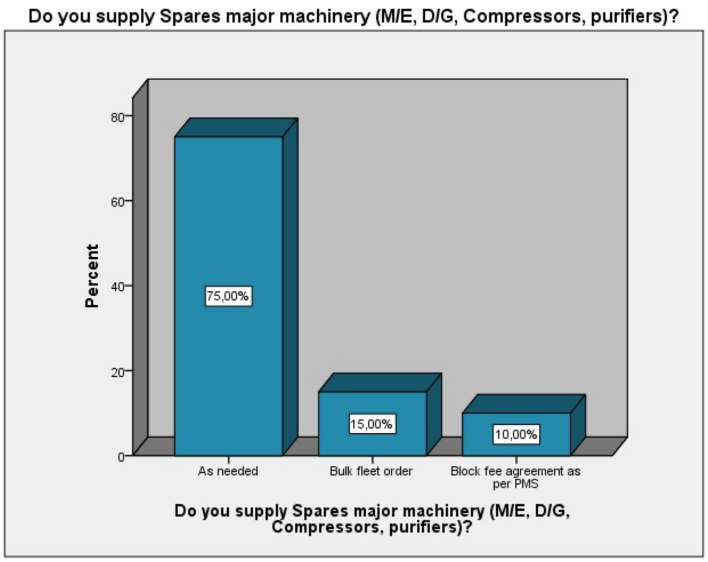
f %: Valid percent %



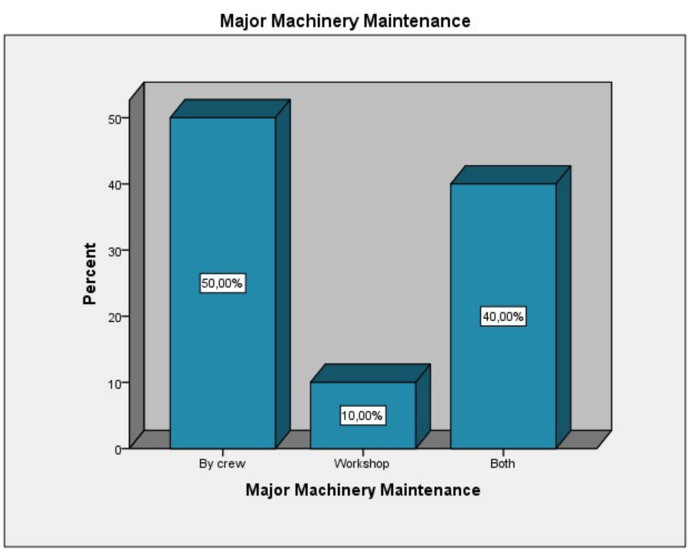
Graph 8: Maintenance major machinery (M/E, D/G, Compressors, purifiers)



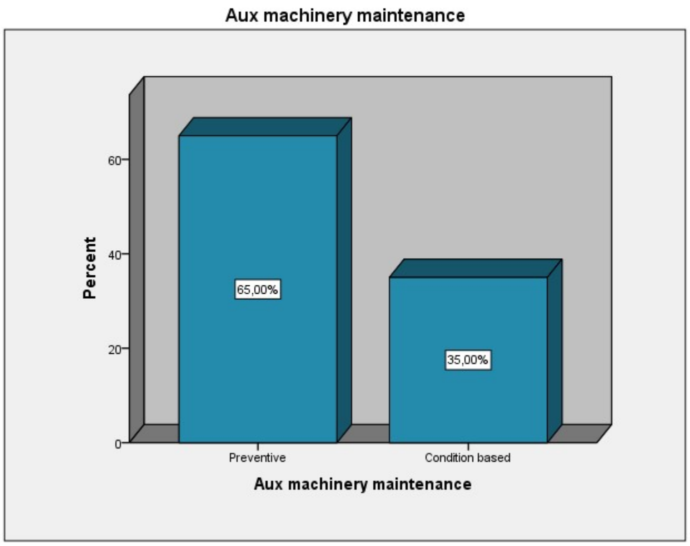
Graph 9: Supply Spares major machinery (M/E, D/G, Compressors, purifiers):



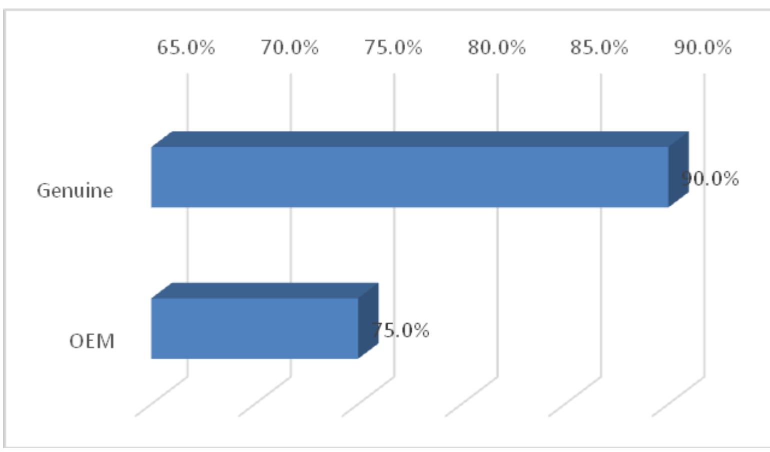
Graph 10: Do you supply Spares major machinery (M/E, D/G, Compressors, purifiers)?



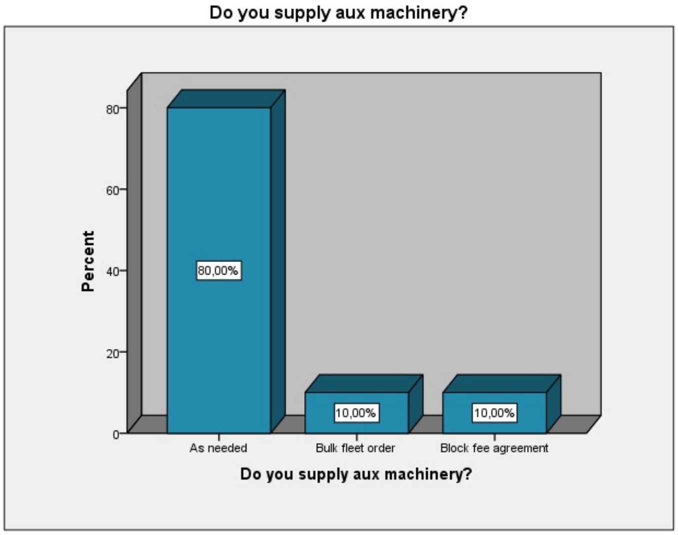
Graph 11: Major Machinery Maintenance



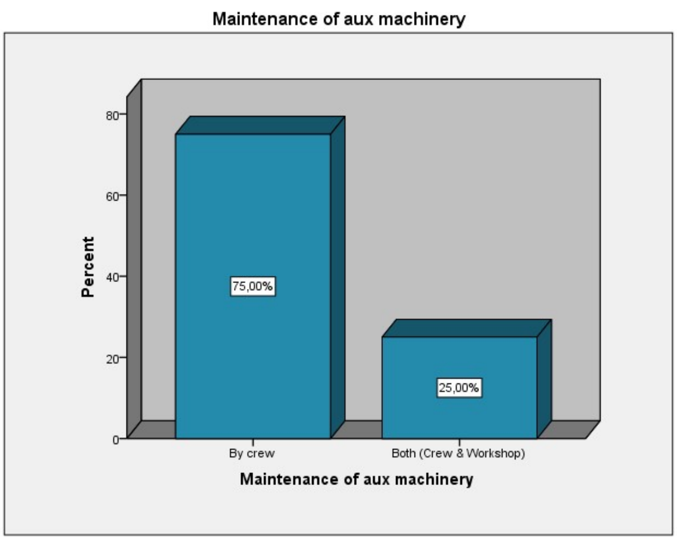
Graph 12: Aux machinery maintenance



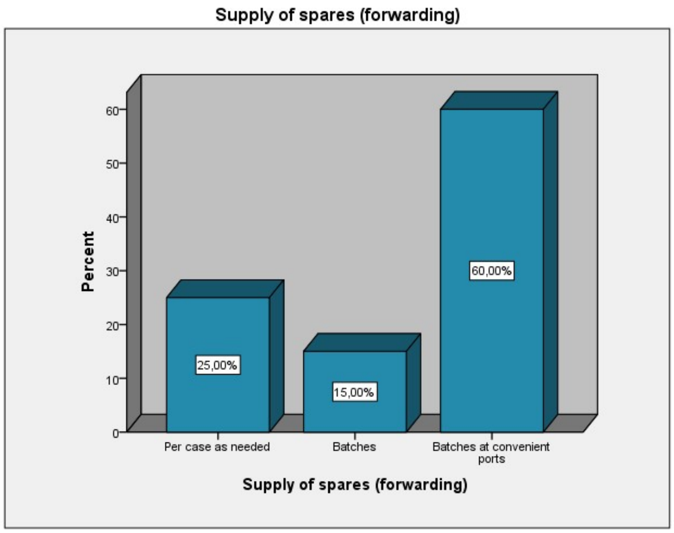
Graph 13: Supply Spares aux machinery



Graph 14: Do you supply aux machinery?



Graph 15: Maintenance of aux machinery



Graph 16: Supply of spares (forwarding)

Graph 17: Supply of stores

9.1.3. Service

In the current chapter, it is represented the features that are linked to service. Below, Table 5 and Graphs from 18 to 28 indicate that 70,0% (N=14) stated that services for Radio and safety equipment are performed per case, while 30,0% (N=6) with fee agreement.

Also, 95,0% (N=19) claimed that repair and maintenance services are performed per case, whereas 5,0% (N=1) following fee agreement. Equally, 68,4% (N=13) answered that Class/Flag/ISM services are carried out with fee agreement and 31,6% (N=6) per case.

Moreover, 50,0% (N=10) declared that dry docking location/Yard is performed per case, 35,0% (N=7) per case and with fleet agreement, while 15,0% (N=3) with fleet agreement. Besides, 50,0% (N=10) responded that lubricants are supplied per case one agreed supplier, 35,0% (N=7) per case from any maker/supplier, whereas 15,0% (N=3) with minimum supply agreement with specific supplier. Additionally, 47,4% (N=9) referred that paints are supplied per case one agreed supplier, 42,1% (N=8) per case from any maker/supplier, while 10,5% (N=2) with minimum supply agreement with specific supplier.

In terms of MARPOL compliance method, 80,0% (N=16) mentioned the VLSFO method, 10,0% (N=2) LS MGO and 10,0% (N=2) the Scrubber. With regard to BWTS, 40,0% (N=8) referred to Filter-UV, 35,0% (N=7) Electrolysis, 10,0% (N=2) N/A, whereas 15,0% (N=3) chose the category "other".

Also, 60,0% (N=12) claimed that the major machinery breakdown per vessel happens less than 4 years and more than 1 year, 35,0% (N=7) less than 1 year and 5,0% (N=1) more than 4 years. In addition, 80,0% (N=16) answered that aux machinery breakdown per vessel happens less than 4 years and more than 1 year, 15,0% (N=3) less than 1 year, while 5,0% (N=1) more than 4 years. Finally, with regard to yearly spares and repairs/maintenance service cost (incl. class, radio/nav.aids/safety) per ship, 55,0% (N=11) responded 350,000-500,000 $, 40,0% (N=8) Less than 350,000 $, whereas 5,0% (N=1) 350,000-500,000 $.

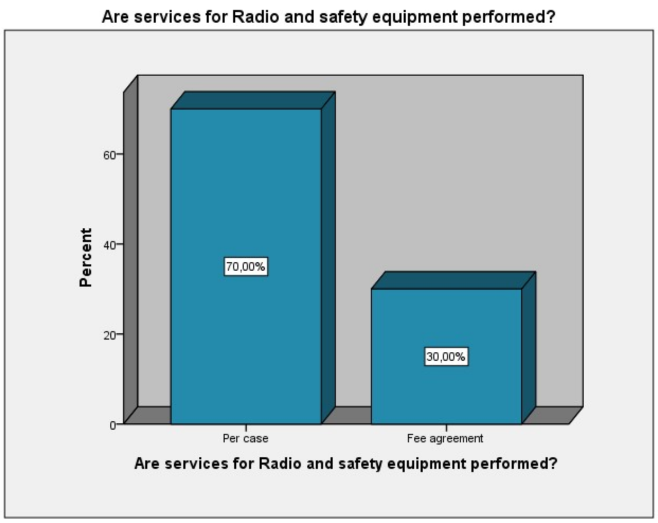
Table 5: Service

Feature	Category	N	f%
Are services for Radio and safety equipment performed	Per case	14	70,0
	Fee agreement	6	30,0
Are Repair and Maintenance services performed?	Per case	19	95,0
	Fee agreement	1	5,0
Are Class/Flag/ISM services performed?	Per case	6	31,6
	Fee agreement	13	68,4
Dry docking location/Yard	Per case	10	50,0
	Fleet agreement	3	15,0
	Both	7	35,0
Are lubricants supplied?	Per case from any maker/supplier	7	35,0
	Per case one agreed supplier	10	50,0
	Minimum Supply agreement with specific supplier	3	15,0
Are Paints supplied?	Per case from any maker/supplier	8	42,1
	Per case one agreed supplier	9	47,4
	Minimum Supply agreement with specific supplier	2	10,5
MARPOL 0.5% sulfur emissions	Scrubber	2	10,0

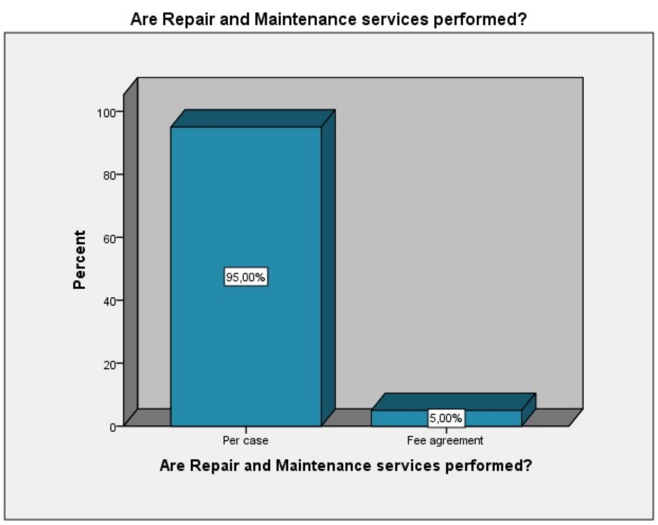
compliance method (Majority of the fleet)	VLSFO	16	80,0
	LS MGO	2	10,0
BWTS	Electrolysis	7	35,0
	Filter-UV	8	40,0
	Other	3	15,0
	N/A	2	10,0
Major Machinery breakdown occurrence frequency per year per vessel	More than 4	1	5,0
	Less than 4 and more than 1	12	60,0
	Less than 1	7	35,0
Aux Machinery breakdown occurrence frequency per year per vessel	More than 4	1	5,0
	Less than 4 and more than 1	16	80,0
	Less than 1	3	15,0
Yearly Spares and repairs/maintenance service cost (incl. class, radio/nav.aids/safety) per ship	Less than 350,000 $	8	40,0
	350,000-500,000 $	11	55,0
	350,000-500,000 $	1	5,0

N: Frequency

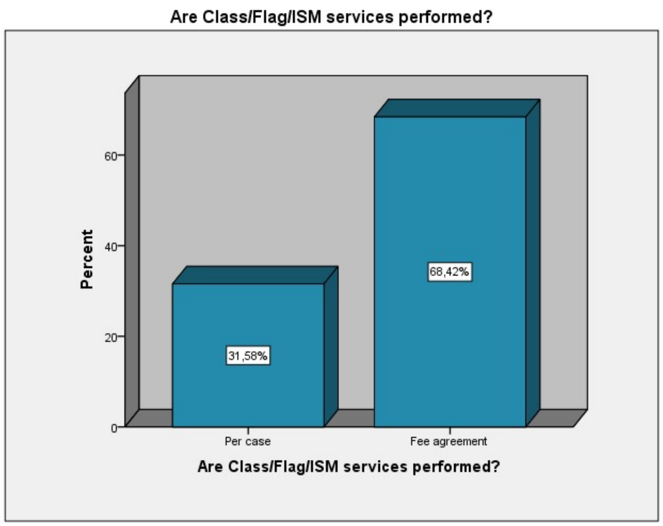
f %: Valid percent %



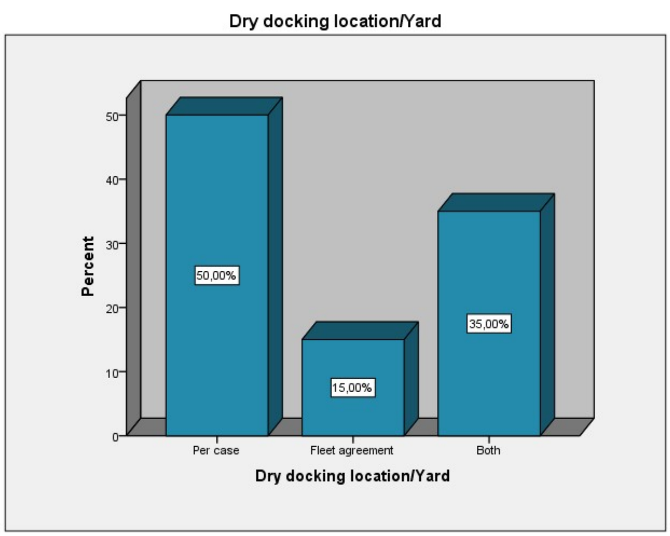
Graph 18: Are services for Radio and safety equipment performed?



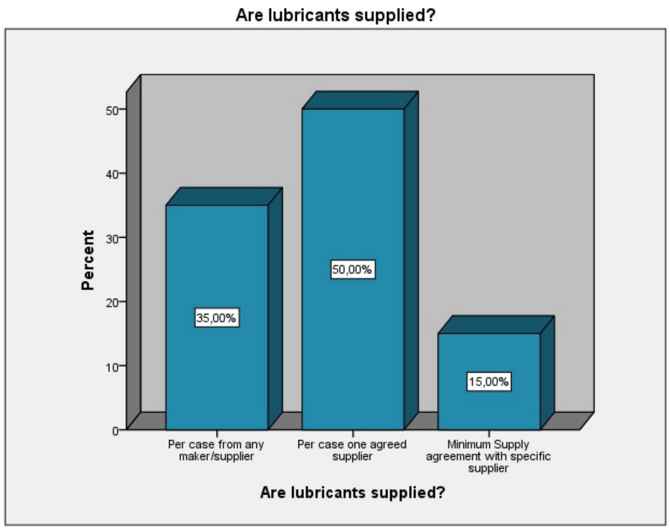
Graph 19: Are Repair and Maintenance services performed?



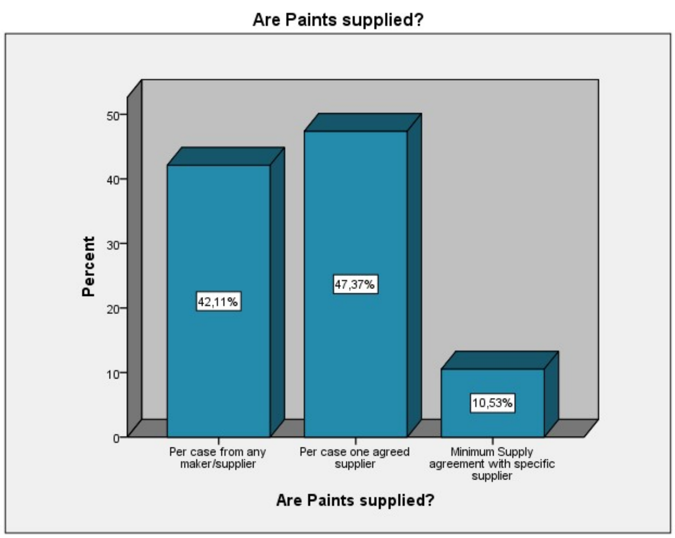
Graph 20: Are Class/Flag/ISM services performed?



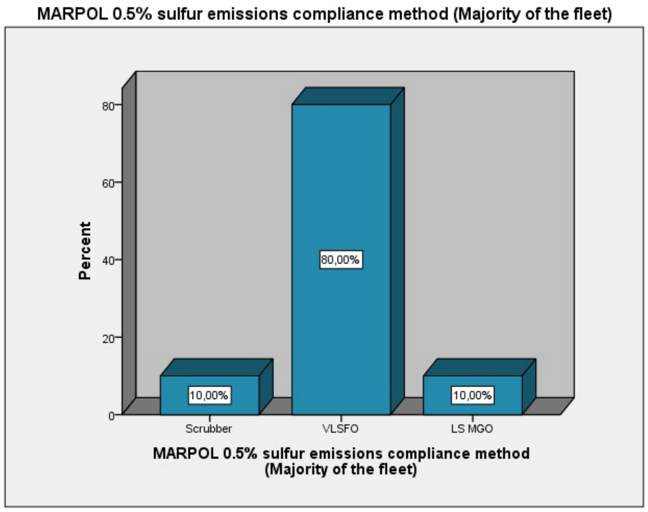
Graph 21: "Dry docking location/Yard"



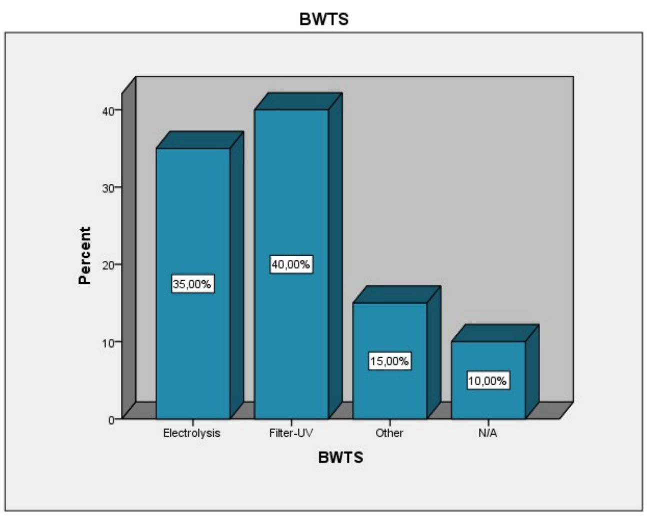
Graph 22: Are lubricants supplied?



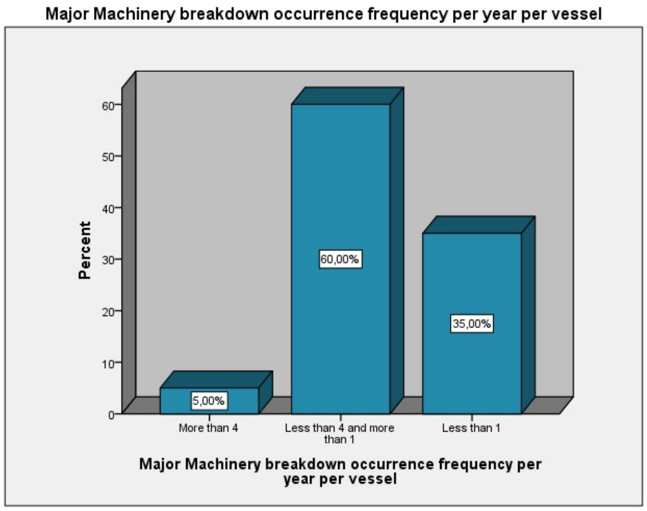
Graph 23: Are Paints supplied?



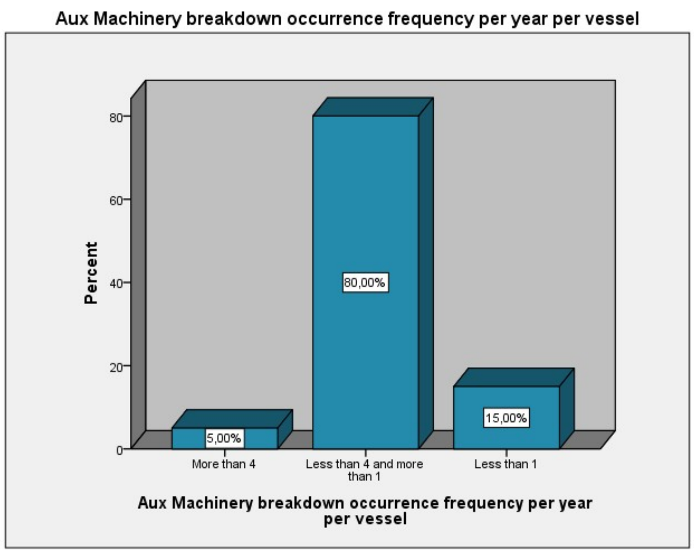
Graph 24: MARPOL 0.5% sulfur emissions compliance method (Majority of the fleet)



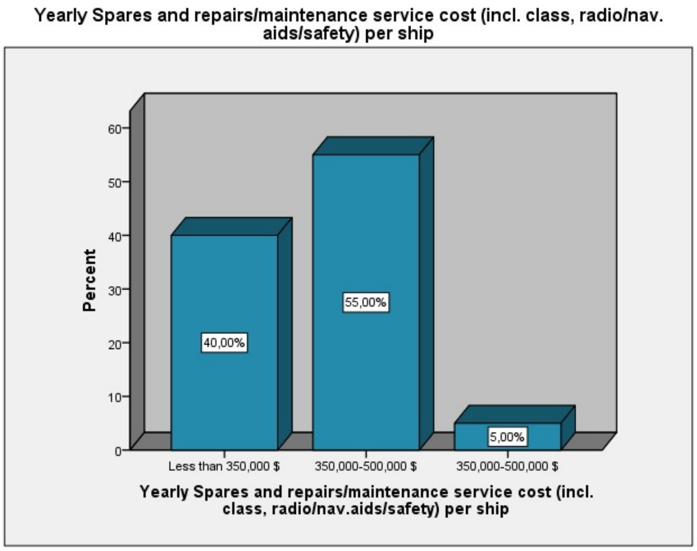
Graph 25: BWTS



Graph 26: Major Machinery breakdown occurrence frequency per year per vessel



Graph 27: Aux Machinery breakdown occurrence frequency per year per vessel



Graph 28: Yearly Spares and repairs/maintenance service cost (incl. class, radio/nav.aids/safety) per ship

9.2. Inferential Statistics

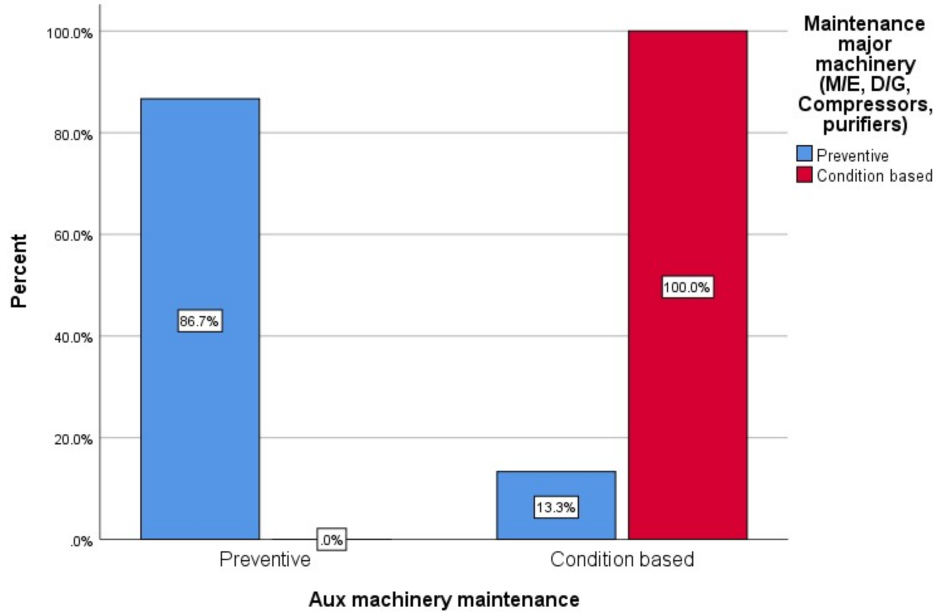
9.2.1. Dependencies for Maintenance

Table 6 (and Graph 29) shows the results of the Chi-squared test to check the dependence between "Maintenance major machinery" and "Aux machinery maintenance”. The results indicate a dependence between major machinery and aux machinery maintenance ($X^2(1)$ =12,381, p=0,001).

Specifically, while the percentage of companies that do preventive aux machinery maintenance is 65,0%, this percentage increases to 86,7% for companies that do preventive major machinery maintenance.

Table 6: Maintenance major machinery*Aux machinery maintenance, Chi-squared test

		Aux machinery maintenance			
$X^2(1)$=12,381, p=0,001		**Preventive**		**Condition based**	
		N	**%**	**N**	**%**
Maintenance major machinery (M/E, D/G, Compressors, purifiers)	**Preventive**	13	86,7%	2	13,3%
	Condition based	0	0,0%	5	100,0%
	Total	13	65,0%	7	35,0%



Graph 29: Maintenance major machinery*Aux machinery maintenance

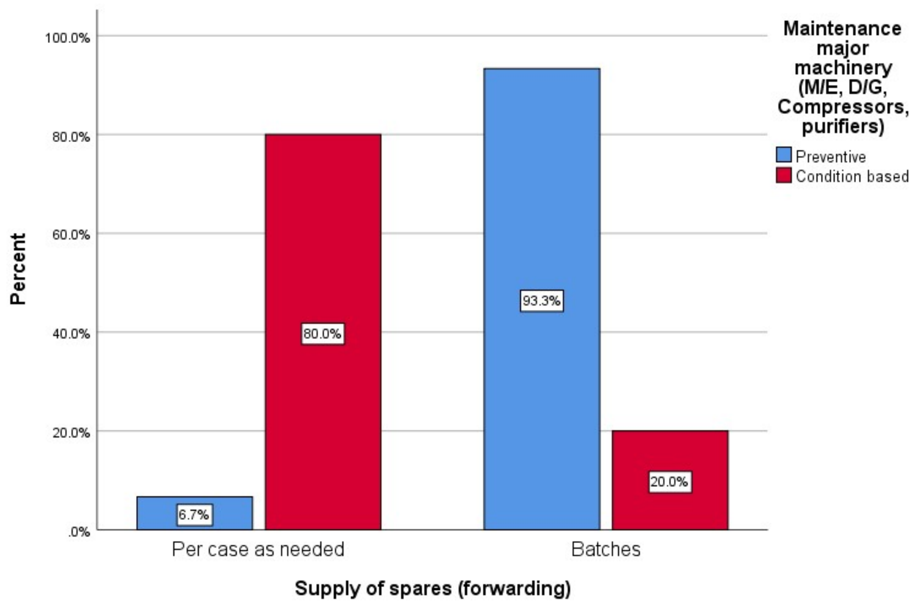
Table 7 (and Graph 30) shows the results of the Chi-squared test to check the dependence between "Maintenance major machinery" and "Supply of spares (forwarding)". The results indicate a dependence between major machinery maintenance and forwarding supply of spares ($X^2(1)$ =10,756, p=0,005).

Specifically, while the percentage of companies that do per case as needed supply of spares is 25,0%, this percentage increases to 80% for companies that do condition based major machinery maintenance.

Table 7: Maintenance major machinery*Supply of spares (forwarding), Chi-squared test

		Supply of spares (forwarding)			
$X^2(1)$=10,756, p=0,005		**Per case as needed**		**Batches**	
		N	**%**	**N**	**%**
Maintenance major	**Preventive**	1	6,7%	14	93,3%

machinery (M/E, D/G, Compressors, purifiers)	**Condition based**	4	80,0%	1	20,0%
	Total	5	25,0%	15	75,0%



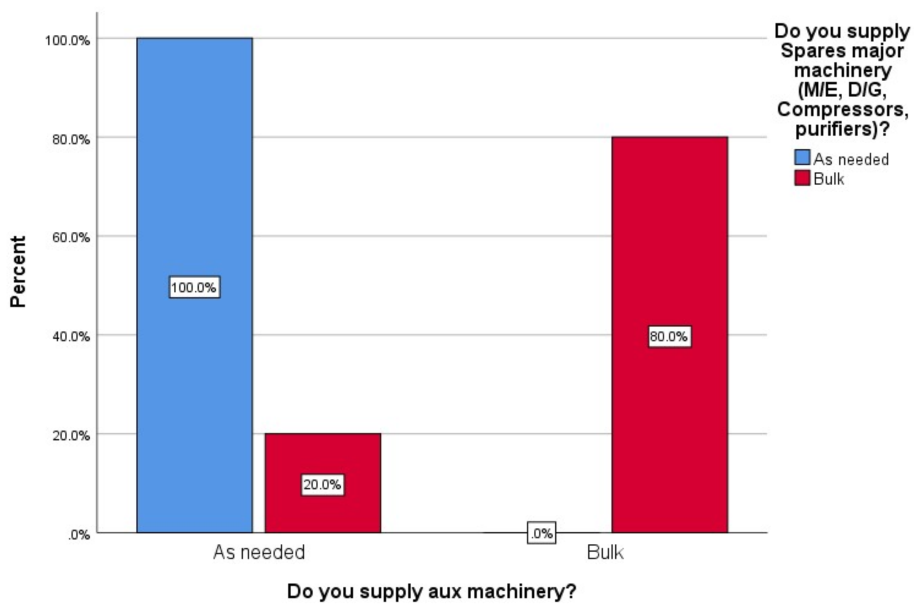
Graph 30: Maintenance major machinery*Supply of spares (forwarding)

Table 8 (and Graph 31) shows the results of the Chi-squared test to check the dependence between "Do you supply Spares major machinery (M/E, D/G, Compressors, purifiers)?" and "Do you supply aux machinery?". The results indicate a dependence between the supply of spares for major and aux machinery, ($X^2(1)$ =15,000, p=0,001).

Specifically, while the percentage of companies that supply aux machinery as needed is 80,0%, this percentage increases to 100% for companies that supply spares major machinery as needed.

Table 8: Do you supply Spares major machinery (M/E, D/G, Compressors, purifiers)? *Do you supply aux machinery? Chi-squared test

$X^2(1)$=15,000, p=0,001		Do you supply aux machinery?			
		As needed		Bulk	
		N	%	N	%
Do you supply Spares major machinery (M/E, D/G, Compressors, purifiers)?	As needed	15	100,0%	0	0,0%
	Bulk	1	20,0%	4	80,0%
	Total	16	80,0%	4	20,0%



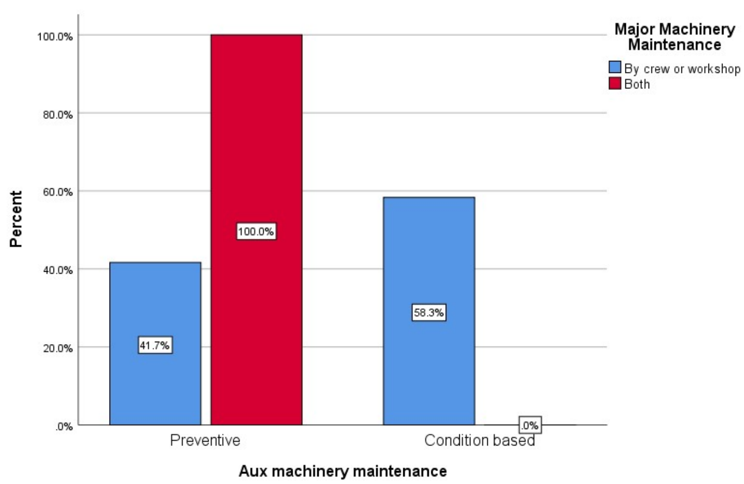
Graph 31: Supply of spares major machinery*Supply aux machinery

Table 9 (and Graph 32) shows the results of the Chi-squared test to check the dependence between "Major Machinery Maintenance" and "Aux machinery maintenance". The results indicate a dependence ($X^2(1)$ =7,179, p=0,010).

Specifically, while the percentage of companies that do preventive aux machinery maintenance is 65,0%, this percentage increases to 100% for companies that do major machinery maintenance by both crew and workshop.

Table 9: Major Machinery Maintenance*Aux machinery maintenance, Chi-squared test

		Aux machinery maintenance			
$X^2(1)=7{,}179$, p=0,010		Preventive		Condition based	
		N	%	N	%
Major Machinery Maintenance	**By crew or workshop**	5	41,7%	7	58,3%
	Both	8	100,0%	0	0,0%
	Total	13	65,0%	7	35,0%



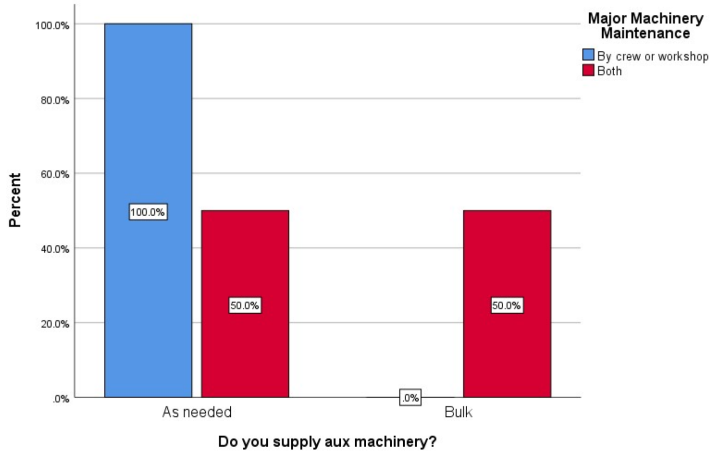
Graph 32: Major Machinery Maintenance*Aux machinery maintenance

Table 10 (and Graph 33) shows the results of the Chi-squared test to check the dependence between "Major Machinery Maintenance" and "Do you supply aux machinery?". The results indicate a dependence ($X^2(1)=7,500$, $p=0,014$).

Specifically, while the percentage of companies that supply aux machinery as needed is 80,0%, this percentage increases to 100% for companies that do major machinery maintenance by crew or workshop.

Table 10: Major Machinery Maintenance*Do you supply aux machinery? Chi-squared test

		Do you supply aux machinery?			
$X^2(1)=7,500$, $p=0,014$		**As needed**		**Bulk**	
		N	**%**	**N**	**%**
Major Machinery Maintenance	**By crew or workshop**	12	100,0%	0	0,0%
	Both	4	50,0%	4	50,0%
	Total	16	80,0%	4	20,0%



Graph 33: Major Machinery Maintenance*Do you supply aux machinery?

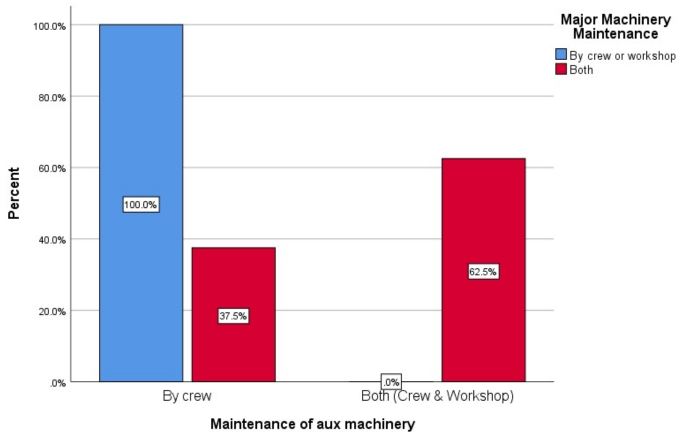
Table 11 (and Graph 34) shows the results of the Chi-squared test to check the dependence between "Major Machinery Maintenance" and "Maintenance of aux machinery". The results indicate a dependence between how major and aux machinery maintenance ($X^2(1)$ =10,000, p=0,004).

Specifically, while the percentage companies that do aux machinery maintenance by crew is 75,0%, this percentage increases for companies that do major machinery maintenance by crew or workshop to 100,0%.

Table 11: Major Machinery Maintenance*Maintenance of aux machinery, Chi-squared test

		Maintenance of aux machinery			
X^2(1)=10,000, p=0,004		**By crew**		**By Crew & Workshop**	
		N	**%**	**N**	**%**
Major Machinery Maintenance	**By crew or workshop**	12	100,0%	0	0,0%
	Both	3	37,5%	5	62,5%

Total	15	75,0%	5	25,0%



Graph 34: Major Machinery Maintenance*Maintenance of aux machinery

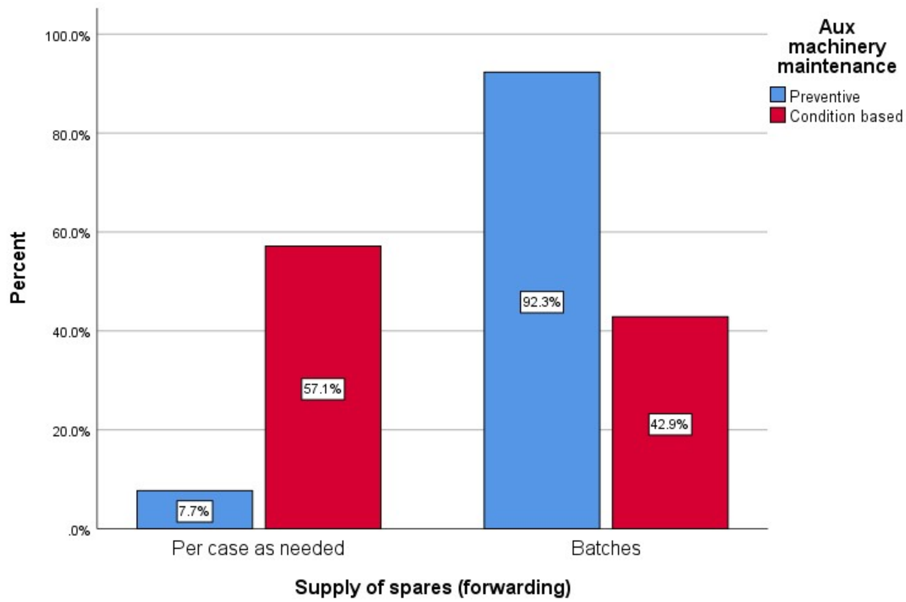
Table 12 (and Graph 35) shows the results of the Chi-squared test to check the dependence between "Aux machinery maintenance" and "Supply of spares (forwarding)". The results indicate a dependence between aux machinery maintenance and forwarding supply of spares ($X^2(1)$ =5,934, p=0,031).

Specifically, while the percentage of companies that do per case as needed supply of spares is 25,0%, this percentage increases to 57,1% for companies that do condition-based aux machinery maintenance.

Table 12: Aux machinery maintenance*Supply of spares (forwarding), Chi-squared test

	Supply of spares (forwarding)			
$X^2(1)$=5,934, p=0,031	**Per case as needed**		**Batches**	
	N	**%**	**N**	**%**

Aux machinery maintenance	**Preventive**	1	7,7%	12	92,3%
	Condition based	4	57,1%	3	42,9%
	Total	5	25,0%	15	75,0%



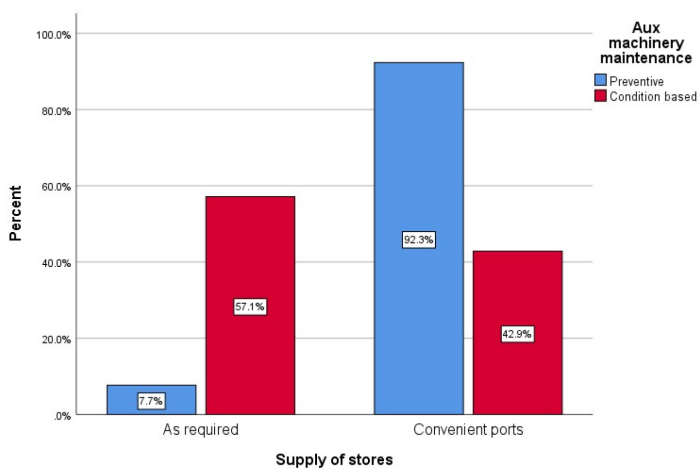
Graph 35: Aux machinery maintenance*Supply of spares (forwarding)

Table 13 (and Graph 36) shows the results of the Chi-squared test to check the dependence between Aux machinery maintenance and Supply of stores. The results indicate a dependence between aux machinery maintenance and the supply of stores (X^2 (1) =5,934, p=0,031).

Specifically, while the percentage of companies that do supply of stores as required is 25,0%, this percentage increases to 57,1% for companies that do condition-based aux machinery maintenance.

Table 13: Aux machinery maintenance*Supply of stores, Chi-squared test

X²(1)=5,934, p=0,031		Supply of stores			
		As required		Convenient ports	
		N	%	N	%
Aux machinery maintenance	**Preventive**	1	7,7%	12	92,3%
	Condition based	4	57,1%	3	42,9%
	Total	5	25,0%	15	75,0%



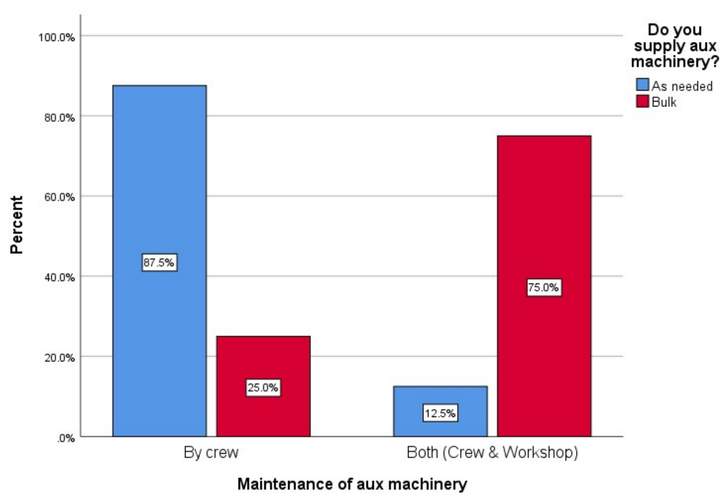
Graph 36: Aux machinery maintenance*Supply of stores

Table 14 (and Graph 37) shows the results of the Chi-squared test to check the dependence between “Do you supply aux machinery?” and “Maintenance of aux machinery”. The results indicate a dependence ($X^2(1)$ =6,667, p=0,032).

Specifically, while the percentage of companies that do aux machinery maintenance by crew is 75,0%, this percentage increases to 87,5% for companies that supply aux machinery.

Table 14: Do you supply aux machinery? * Maintenance of aux machinery, Chi-squared test

		Maintenance of aux machinery			
$X^2(1)=6{,}667$, p=0,032		**By crew**		**By crew and Workshop**	
		N	**%**	**N**	**%**
Do you supply aux machinery?	**As needed**	14	87,5%	2	12,5%
	Bulk	1	25,0%	3	75,0%
	Total	15	75,0%	5	25,0%



Graph 37: Do you supply aux machinery? * Maintenance of aux machinery

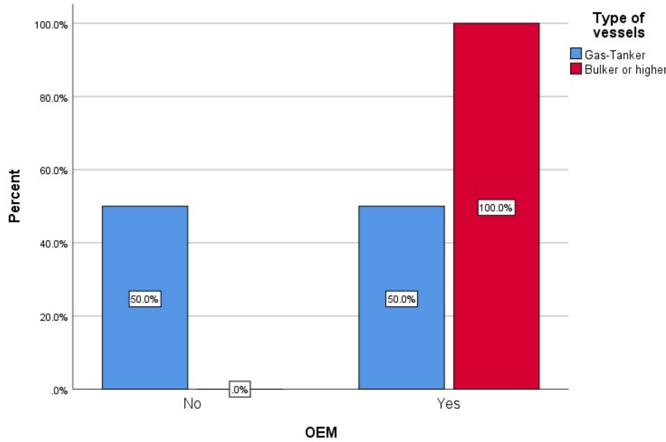
9.2.2. Dependencies between Maintenance and general data

Table 15 (and Graph 38) shows the results of the Chi-squared test to check the dependence between "Type of vessels" and "Aux machinery supply spares by OEM". The results indicate a dependence between the type of vessels and whether the aux machinery supply spares are from an OEM ($X^2(1)$ =6,667, p=0,016)

Specifically, while the percentage of the sample that gets aux machinery supply spares from OEM is 75,0%, this percentage increases to 100% for companies of bulker or higher type of vessels

Table 15: Type of vessels*Aux machinery supply spares by OEM, Chi-squared test

		Aux machinery supply spares by OEM			
$X^2(1)$=6,667, p=0,016		**No**		**Yes**	
		N	**%**	**N**	**%**
Type of vessels	**Gas-Tanker**	5	50,0%	5	50,0%
	Bulker or higher	0	0,0%	10	100,0%
	Total	5	25,0%	15	75,0%



Graph 38: Type of vessels*Aux machinery supply spares by OEM

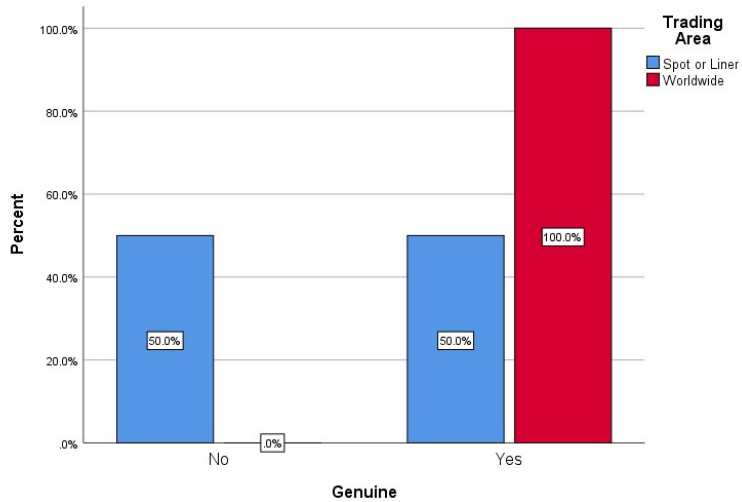
Table 16 (and Graph 39) shows the results of the Chi-squared test to check the dependence between "Trading Area" and "Genuine aux machinery supply spares". The results indicate a dependence between the trading area and whether the aux machinery supply spares are genuine ($X^2(1)$ =8,889, p=0,032).

Specifically, while the percentage of companies that do genuine aux machinery supply spares is 90,0%, this percentage increases to 100% for companies of worldwide trading areas.

Table 16: Trading Area*Genuine aux machinery supply spares, Chi-squared test

		Genuine			
X^2(1)=8,889, p=0,032		**No**		**Yes**	
		N	**%**	**N**	**%**
Trading Area	**Spot or Liner**	2	50,0%	2	50,0%
	Worldwide	0	0,0%	16	100,0%

Total	2	10,0%	18	90,0%



Graph 39: Trading Area*Genuine aux machinery supply spares

9.2.3. Dependencies for Service

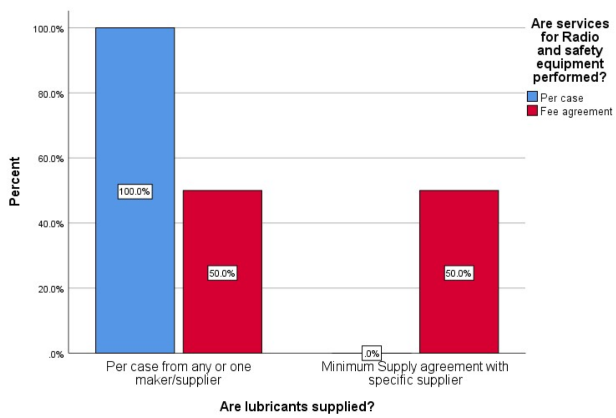
Table 17 (and Graph 40) shows the results of the Chi-squared test to check the dependence between "Are services for Radio and safety equipment performed?" and "Are lubricants supplied?". The results indicate a dependence between the services for Radio and safety equipment and how lubricants are supplied ($X^2(1)$ =8,235, p=0,018).

Specifically, while the percentage of the sample that lubricants are supplied per case from any or one maker/supplier is 85,0%, this percentage increases to 100% for companies that provide services for Radio and safety equipment per case.

Table 17: Are services for Radio and safety equipment performed? * Are lubricants supplied? Chi-squared test

	Are lubricants supplied?	
$X^2(1)$=8,235, p=0,018	**Per case from any or one**	**Minimum Supply agreement with**

		maker/supplier		specific supplier	
		N	%	N	%
Are services for Radio and safety equipment performed?	**Per case**	14	100,0%	0	0,0%
	Fee agreement	3	50,0%	3	50,0%
	Total	17	85,0%	3	15,0%



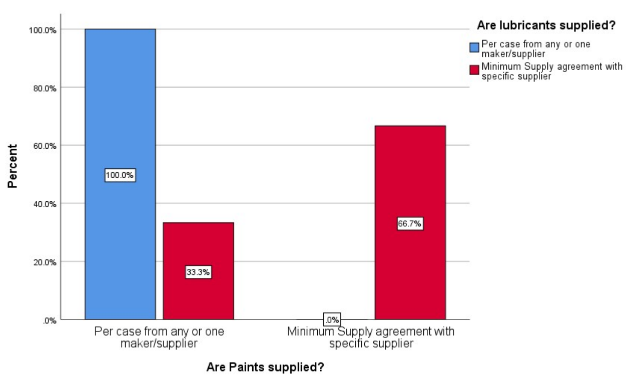
Graph 40: Are services for Radio and safety equipment performed? * Are lubricants supplied

Table 18 (and Graph 41) shows the results of the Chi-squared test to check the dependence between “Are lubricants supplied?” and “Are Paints supplied?”. The results indicate a dependence between how lubricants and paints are supplied, ($X^2(1) =11,922$, $p=0,018$).

Specifically, while the percentage of the sample that paints are supplied per case from any or one maker/supplier is 89,5%, this percentage increases to 100% for companies that lubricants are supplied per case from any or one maker/supplier.

Table 18: Are lubricants supplied? * Are Paints supplied? Chi-squared test

$X^2(1)=11,922$, p=0,018		**Are Paints supplied?**			
		Per case from any or one maker/supplier		**Minimum Supply agreement with specific supplier**	
		N	**%**	**N**	**%**
Are lubricants supplied?	**Per case from any or one maker/supplier**	16	100,0%	0	0,0%
	Minimum Supply agreement with specific supplier	1	33,3%	2	66,7%
	Total	17	89,5%	2	10,5%



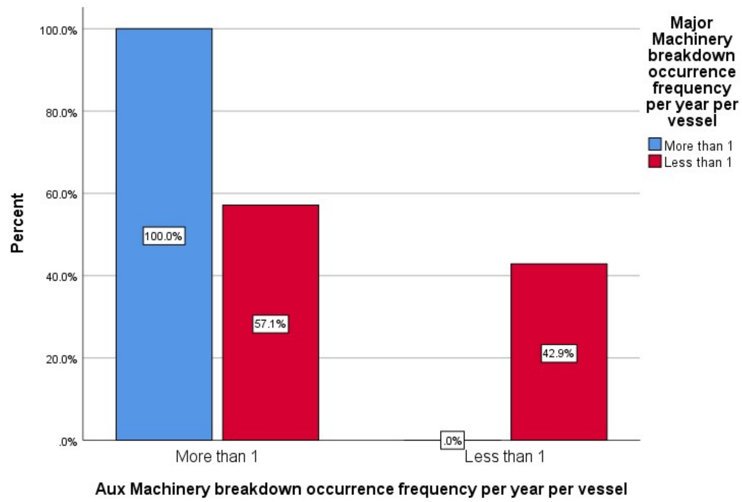
Graph 41: Are lubricants supplied? * Are Paints supplied?

Table 19 (and Graph 42) shows the results of the Chi-squared test to check the dependence between “Major Machinery breakdown occurrence frequency per year per vessel” and “Aux Machinery breakdown occurrence frequency per year per vessel”. The results indicate a dependence between major and aux machinery breakdown occurrence frequency per year per vessel, ($X^2(1)=6,555$, p=0,031).

Specifically, while the percentage of the sample that had more than one aux machinery breakdown per year per vessel is 85,0%, this percentage increases to 100% for companies that have more than one major machinery breakdown per year per vessel.

Table 19: Major Machinery breakdown occurrence frequency per year per vessel*Aux Machinery breakdown occurrence frequency per year per vessel, Chi-squared test

		Aux Machinery breakdown occurrence frequency per year per vessel			
$X^2(1)=6{,}555$, p=0,031		**More than 1**		**Less than 1**	
		N	**%**	**N**	**%**
Major Machinery breakdown occurrence frequency per year per vessel	**More than 1**	13	100,0%	0	0,0%
	Less than 1	4	57,1%	3	42,9%
	Total	17	85,0%	3	15,0%



Graph 42: Major Machinery breakdown occurrence frequency per year per vessel*Aux Machinery breakdown occurrence frequency per year per vessel

9.2.4. Dependencies between Service and General data

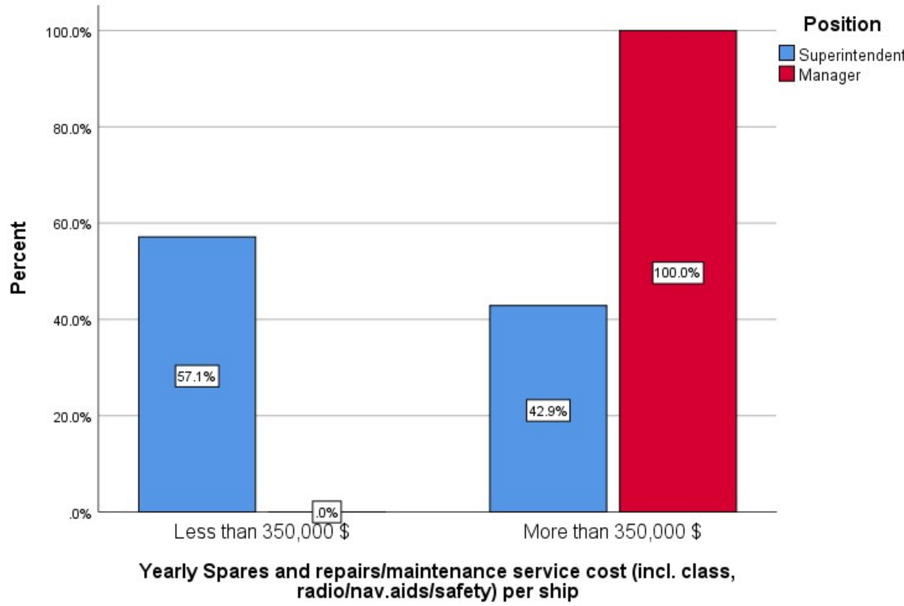
Table 20 (and Graph 43) shows the results of the Chi-squared test to check the dependence between "Position" and "Yearly Spares and repairs/maintenance service cost". The results indicate a dependence between the position of the crew and the Yearly Spares and repairs/maintenance service cost, ($X^2(1)$ =5,714, p=0,042).

Specifically, while the percentage of the sample that the Yearly Spares and repairs/maintenance service cost was less than 350,000 $ is 40,0%, this percentage increases to 57,1% for companies that participant had the position of the superintendent.

Table 20: Position*Yearly Spares and repairs/maintenance service cost, Chi-squared test

		Yearly Spares and repairs/maintenance service cost			
$X^2(1)$=5,714, p=0,042		**Less than 350,000 $**		**More than 350,000 $**	
		N	**%**	**N**	**%**
Position	**Superintendent**	8	57,1%	6	42,9%

Manager	0	0,0%	6	100,0%
Total	8	40,0%	12	60,0%



Graph 43: Position*Yearly Spares and repairs/maintenance service cost

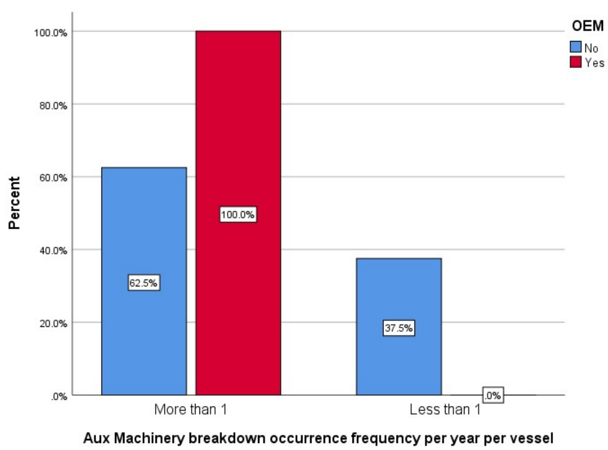
9.2.5. Dependencies between Maintenance and Service

Table 21 (and Graph 44) shows the results of the Chi-squared test to check the dependence between "Machinery supply spares by OEM" and "Aux Machinery breakdown occurrence frequency per year per vessel". The results indicate a dependence ($X^2(1)$ =5,294, p=0,049).

Specifically, while the percentage of the sample that had more than one aux machinery breakdown per year per vessel is 85,0%, this percentage increases to 100% for companies that get machinery supply spares from an OEM.

Table 21: Machinery supply spares by OEM*Aux Machinery breakdown occurrence frequency per year per vessel, Chi-squared test

$X^2(1)=5,294$, p=0,049		Aux Machinery breakdown occurrence frequency per year per vessel			
		More than 1		**Less than 1**	
		N	**%**	**N**	**%**
Machinery supply spares by OEM	**No**	5	62,5%	3	37,5%
	Yes	12	100,0%	0	0,0%
	Total	17	85,0%	3	15,0%



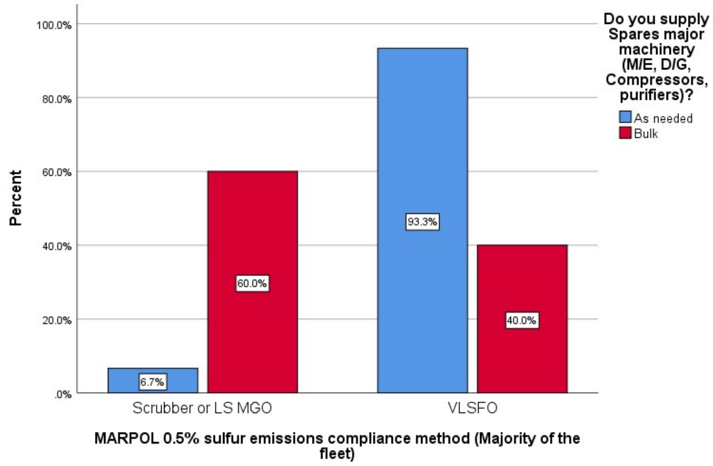
Graph 44: Machinery supply spares by OEM *Aux Machinery breakdown occurrence frequency per year per vessel

Table 22 (and Graph 45) shows the results of the Chi-squared test to check the dependence between “Do you supply Spares major machinery (M/E, D/G, Compressors, purifiers)?” and “MARPOL 0.5% sulfur emissions compliance method (Majority of the fleet)”. The results indicate a dependence ($X^2(1)$ =6,667, p=0,032).

Specifically, while the percentage of the sample that had Scrubber or LS MGO compliance is 20,0%, this percentage increases to 60,0% for companies that supply major machinery in bulk.

Table 22: Do you supply Spares major machinery? * MARPOL Emissions compliance, Chi-squared test

		MARPOL 0.5% sulfur emissions compliance method (Majority of the fleet)			
$X^2(1)$=6,667, p=0,032		**Scrubber or LS MGO**		**VLSFO**	
		N	**%**	**N**	**%**
Do you supply Spares major machinery (M/E, D/G, Compressors, purifiers)?	**As needed**	1	6,7%	14	93,3%
	Bulk	3	60,0%	2	40,0%
	Total	4	20,0%	16	80,0%



Graph 45: Do you supply Spares major machinery? * MARPOL Emissions compliance

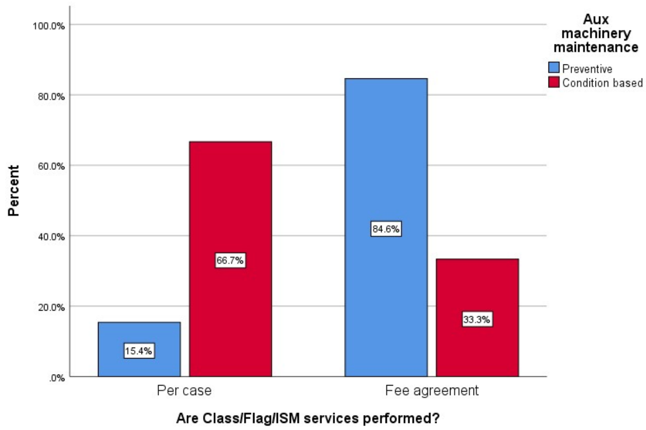
Table 23 (and Graph 46) shows the results of the Chi-squared test to check the dependence between "Aux machinery maintenance" and "Are Class/Flag/ISM services performed?". The results indicate a dependence ($X^2(1)$ =4,997, p=0,046).

Specifically, while the percentage of the sample that perform Class/Flag/ISM services per case is 31,6%, this percentage increases to 66,7% for companies that do condition-based aux machinery maintenance.

Table 23: Aux machinery maintenance*Are Class/Flag/ISM services performed? Chi-squared test

		Are Class/Flag/ISM services performed?			
$X^2(1)$=4,997, p=0,046		**Per case**		**Fee agreement**	
		N	**%**	**N**	**%**
Aux machinery maintenance	**Preventive**	2	15,4%	11	84,6%
	Condition based	4	66,7%	2	33,3%

Total	6	31,6%	13	68,4%



Graph 46: Aux machinery maintenance*Are Class/Flag/ISM services performed?

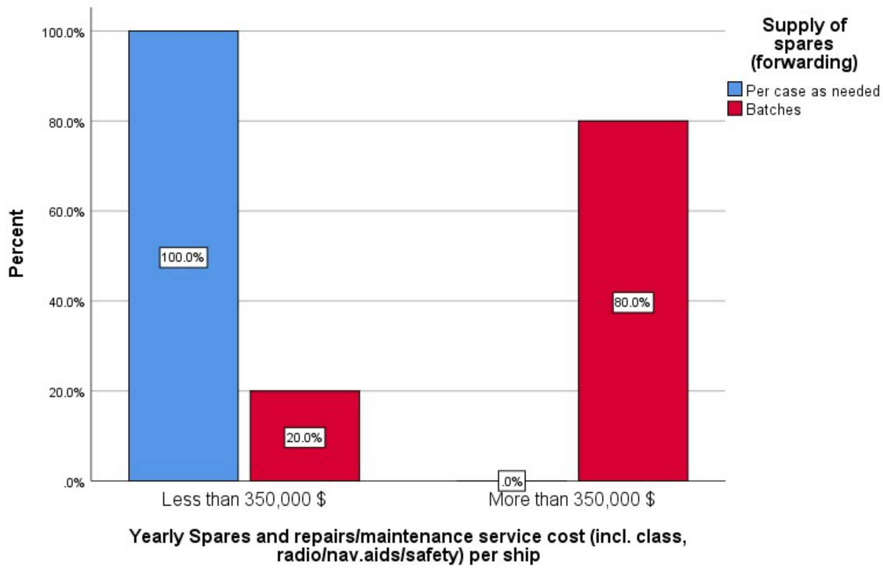
Table 24 (and Graph 47) shows the results of the Chi-squared test to check the dependence between "Supply of spares (forwarding)" and "Yearly Spares and repairs/maintenance service cost". The results indicate a dependence between the forwarding supply of spares and the Yearly Spares and repairs/maintenance service cost, ($X^2(1)$ =10,000, p=0,004).

Specifically, while the percentage of the sample that the Yearly Spares and repairs/maintenance service cost was less than 350,000 $ is 40,0%, this percentage increases to 100% for companies that are forwarding supply of spares per case as needed.

Table 24: Supply of spares (forwarding)*Yearly Spares and repairs/maintenance service cost, Chi-squared test

	Yearly Spares and repairs/maintenance service cost			
$X^2(1)$=10,000, p=0,004	**Less than 350,000 $**		**More than 350,000 $**	
	N	**%**	**N**	**%**

Supply of spares (forwarding)	**Per case as needed**	5	100,0%	0	0,0%
	Batches	3	20,0%	12	80,0%
	Total	8	40,0%	12	60,0%



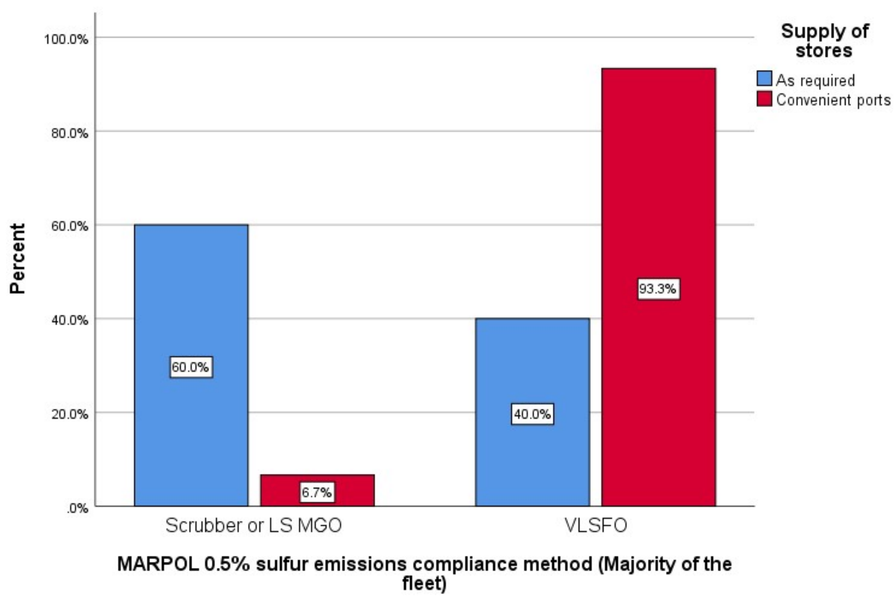
Graph 47: Supply of spares (forwarding)*Yearly Spares and repairs/maintenance service cost

Table 25 (and Graph 48) shows the results of the Chi-squared test to check the dependence between "Supply of stores" and "MARPOL 0.5% sulfur emissions compliance method (Majority of the fleet)". The results indicate a dependence between the supply of stores and the MARPOL Emissions compliance ($X^2(1) = 6{,}667$, $p=0{,}032$).

Specifically, while the percentage of the sample that had Scrubber or LS MGO compliance is 20,0%, this percentage increases to 60% for companies that supply of stores as required.

Table 25: Supply of stores*MARPOL Emissions compliance, Chi-squared test

		MARPOL 0.5% sulfur emissions compliance method (Majority of the fleet)			
$X^2(1)=6,667$, p=0,032		**Scrubber or LS MGO**		**VLSFO**	
		N	**%**	**N**	**%**
Supply of stores	**As required**	3	60,0%	2	40,0%
	Convenient ports	1	6,7%	14	93,3%
	Total	4	20,0%	16	80,0%



Graph 48: Supply of stores*MARPOL Emissions compliance

10. Research Conclutions

In this research participated 20 ship companies with the majority of participants that represented them to be in the technical department, having the position of Superintendent. Regarding the types of vessels, the majority had tankers or bulkers, while the average fleet age in most cases was over than 5 years. As for the type of charter the majority had either voyage or time charter in the 85% of cases. Finally, the majority of the participants stated that their company has worldwide trading area, while the top 4 crew nationality was almost equally distributed between Hellenic, Eastern EU, Filipino or some other nationality.

Regarding the general features that are related to the Major Machinery Maintenance, in most cases the companies conducted preventive maintenance for major machinery, used genuine and OEM supply spares, while they supplied spares for major machinery as needed. Also, the major machinery maintenance was conducted in half cases by crew or by both crew and the workshop in 40% of cases.

As for the general features that are related to the Aux Machinery Maintenance the majority of the companies conducted preventive maintenance for aux machinery, used genuine and OEM supply spares, while they supplied spares as needed. In addition, the aux machinery maintenance was mainly conducted by crew.

In regards with the supply of spare, the forwarding in the majority was performed in batches at convenient ports, while the supply of stores was carried out per 3-4 months in convenient ports.

Regarding the services that are performed, the majority of the companies perform per case services for Radio and safety equipment, repair and maintenance services, while Class/Flag/ISM services are performed after fee agreement. In addition, half of the companies provide dry docking location/yard per case while the 35% both per case and after fleet agreement.

Furthermore, the majority of the companies supplied lubricants and paints either per case from any maker/supplier or per case from one agreed supplier. Also, in regards with the MARPOL compliance method, most of the companies were compliant with the VLSFO method, while in terms of BWTS, the most companies referred to Electrolysis and Filter-UV.

Additionally, the majority of the companies claimed that the major and aux machinery breakdown per vessel happens less than 4 times per and more than 1 times per year. Finally, the companies spend less than 500,000 $ per year in spares and repairs/maintenance service.

From the analysis of the variables of maintenance it was emerged that companies which perform preventive maintenance for major machinery, also perform preventive maintenance for aux machinery, while that companies which perform condition-based maintenance for major machinery, also perform condition-based maintenance for aux machinery.

Furthermore, it arose that companies which perform preventive maintenance for major machinery perform forwarding supply of spares in batches, while that companies which perform condition-based maintenance for major machinery perform forwarding supply of spares per case as needed.

Also, the companies that supplied spares for major machinery as needed, supplied also aux machinery as needed, while the companies that supplied spares for major machinery in bulk, supplied also aux machinery in bulk.

In addition, another result from the analysis was that, the companies that conduct major machinery maintenance by crew or workshop, perform condition-based aux machinery maintenance, while companies that conduct major machinery maintenance both by crew and workshop perform preventive aux machinery maintenance.

Also, it emerged that the companies that perform major machinery maintenance by crew or workshop, supply aux machinery entirely as needed and not in bulk, while the companies that perform major machinery maintenance by both crew and workshop, supply aux machinery as needed or bulk equally.

In addition, companies that perform major machinery maintenance by crew or workshop perform maintenance of aux machinery by crew, while companies that perform major machinery maintenance by both crew and workshop, also perform with the same way the maintenance aux machinery.

Furthermore, it arose that the companies that performed preventive aux machinery maintenance were supplying their stores in convenient ports, while those that performed condition-based aux machinery maintenance were supplying their stores as required.

Also, companies that supply aux machinery as needed, perform maintenance of aux machinery by crew while those that supply aux machinery with bulk, perform aux machinery both by crew and workshop.

Testing dependencies between variables of maintenance and general data, it was emerged that companies with bulk or higher vessels use aux machinery supply spares from OEM, while the companies that have a worldwide trading area use genuine aux machinery supply spares.

From the analysis of the variables of service, it was emerged that the companies that they perform services for Radio and safety equipment per case, supply lubricants per case from any or one maker/supplier. In addition, companies that supply lubricants per case from any or one maker/supplier, supply paints with the same way, while those that supplied lubricants after a minimum agreement with specific supplier, performed the same way the supply of paints. In addition, the analysis showed that when where was more than 1 major machinery breakdown occurrence per year per vessel then there were more than 1 aux machinery breakdown occurrence per year per vessel.

Testing dependencies between variables of service and general data, it was emerged that the participants that were holding the position of Manager their company was spending more than 350,000 $ in yearly spares and repairs/maintenance service cost.

Testing dependencies between variables of maintenance and service, it was emerged the companies that get machinery supply spares by OEM had more than 1 aux machinery breakdown occurrence per year per vessel. Moreover, the companies that supplied spares for major machinery in bulk, were compliant with the Scrubber or LS MGO methods while the companies that supplied spares for major machinery as needed, were compliant with the VLSFO method. Also, companies that performed preventive aux machinery maintenance also performed Class/Flag/ISM services after a fee agreement, while companies that condition based preventive aux machinery maintenance performed per case Class/Flag/ISM services. Additionally, companies that were forwarding supply of spares per case as needed had less than 350,000 $ in yearly spares and repairs/maintenance service cost, while those that were forwarding supply of spares with batches had more than 350,000 $ in yearly spares and repairs/maintenance service cost. Finally, the companies that supplied their stores as required were compliant with the Scrubber or LS MGO methods, while the companies that supplied theirs stores in convenient ports, were compliant with the VLSFO method.

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6. Conclusion

The ship's operating finances can be considered in different ways, depending on the type of trade and the way the ship is used. An owner typically uses a ship in one of four ways: for his own commercial activity, in other commercial activities as a pilot, or in other commercial activities through time chartering or general chartering of the ship. In the case of ships used by their owner for their own commercial use, the owner generally assumes full responsibility for all aspects of the cost.

The daily operating costs of a ship, regardless of its type, include crew costs, supplies and storage, maintenance and repairs, insurance, management and overhead. These costs are added to the charter calculations and, of course, also apply in the case of chartered trips and the owner's operation. These are the costs that arise whether the ship is at sea or in port. A ship's voyage costs include fuel loading, harboring, towing and navigation as well as various other port costs. These items are added when there is a move from a time charter to a trip charter calculation

Cargo management costs include the costs of both loading and unloading the cargo together with any claims that may arise on the cargo. Load handling time can be reduced along with the cost of this function by providing good load handling features.

Regarding the ways of reducing the expenses of a ship, a key parameter is the optimization of its design and operation. The concept of optimization translates to finding the best solution through a limited or unlimited number of options. Even if the number of options is finite, it is often so large that it is impossible to evaluate each possible solution and then determine the best option. In general, there are two methods of approaching optimization problems. The first method is the "Direct Search Method", through which the solutions are created by changing parameters either systematically at certain stages or randomly, while the second method is the "Sharp Slope Method", in which solutions are created using certain information about the local slope (in different directions) of the function to be optimized. Most ship design optimization methods are based on steep approaches because they are very effective for smooth functions.

The result of the optimization model should be compared with the types of ships built. Consistent differences can help identify important factors that have been neglected so far in the model. A sensitivity analysis of the underlying types of assessment will provide a bandwidth of the "optimal" solutions and any project within this bandwidth should be considered equivalent. If the bandwidth is too large, the optimization is negligible.

The dependence on variance is difficult to calculate, but the cost is small compared to the other types of costs mentioned. For this reason, differences in asset costs can be neglected. Taxes, interest on loans that cover the initial construction costs and inflation have only negligible effects on the optimization of the main dimensions and can be ignored. Cash flow and initial costs can be optimized by taking into account only the differences in the basic elements of the ship. This simplifies the calculation as only change-dependent components remain. In this case the difference cost often gives more reliable data.

Scheduled maintenance makes it possible to predict the cost of equipment and external manpower required. establish a full control and costs will be reduced. Procurement policy and the budget of consumables, spare parts and supplies play an important role in the company's expenses.

Applying the Fuzzy logic method can in many cases help us better evaluate maintenance options to reduce costs.

Finally, life cycle costs include operating and maintenance costs. If these costs are high after manufacture, the manufacturer must take these factors into account and give priority to minimizing the overall product life cycle. Higher production costs may be preferable if the total life cycle cost ultimately proves to be lower.

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