

Impact of Lifecycle Agreements on Unplanned Maintenance Parts

Filip Svanbäck

Degree Thesis for Bachelor of Engineering

Degree Programme in Industrial Management and Engineering

Vaasa 2025

DEGREE THESIS

Author: Filip Svanbäck
Degree and location: Industrial Management and Engineering, Vaasa
Supervisor(s): Niklas Kallenberg, Novia University of Applied Sciences
Christoffer Herala, Wärtsilä
Title: Impact of Lifecycle Agreements on Unplanned Maintenance Parts

Date: 06.01.2025 Number of pages: 35 Appendices: 5

Abstract

The thesis is made on behalf of Maintenance Planning at Wärtsilä Finland Oy. The purpose of the study is to understand the extent to which an agreement with Wärtsilä affects unplanned parts consumption for customers' engines, and which of Wärtsilä's agreement types have the greatest impact on unplanned parts consumption. The motivation behind the study arose from a recurring internal challenge, Wärtsilä lacked a standardized and reliable way to compare unplanned maintenance performance across vessels and agreement types.

A quantitative research approach was employed, using data from Wärtsilä's internal systems, SAP and Service Configurator. These were used to compare spare parts consumption across vessels operating under different agreements. However, the initial cost-based comparison revealed significant inconsistencies due to contract specific discounts, pricing models and varying customer behaviors, making the data incomparable across agreements. As a result, a four-step framework based on event classification, root cause analysis, contract scope determination and digital logging techniques was created for comparing unscheduled maintenance.

In addition to pointing out serious flaws in the way unplanned maintenance is currently tracked and analyzed, the thesis offers a workable solution. Although the results are based on a small sample of data, the suggested approach provides a scalable way to increase customer satisfaction, lower unforeseen expenses, and improve performance transparency within Wärtsilä as well as possibly for other service-oriented businesses dealing with comparable issues.

Language: English

Key Words: Lifecycle agreements, unplanned maintenance, spare parts, Wärtsilä, maintenance planning

EXAMENSARBETE

Författare: Filip Svanbäck
Utbildning och ort: Produktionsekonomi, Vasa
Handledare: Niklas Kallenberg, Yrkeshögskolan Novia
Christoffer Herala, Wärtsilä
Titel: Livscykelavtalens inverkan på oplanerat underhåll

Datum: 06.01.2025 Sidantal: 35

Bilagor: 5

Abstrakt

Detta examensarbete har utförts på uppdrag av avdelningen för Maintenance Planning vid Wärtsilä Finland Oy och undersöker hur olika typer av livscykelavtal påverkar förbrukningen av reservdelar vid oplanerat underhåll. Idén till arbetet kom av en återkommande intern utmaning där Wärtsilä saknade ett standardiserat och tillförlitligt sätt att jämföra oplanerat underhåll mellan fartyg och avtalstyper.

Syftet med examensarbetet var dels att utvärdera hur olika avtalstyper påverkar användningen av reservdelar vid oplanerat underhåll. Syftet var också att skapa en praktisk och standardiserad metod för att möjliggöra konsekventa och jämförbara analyser mellan olika fartyg. Först användes en kvantitativ metod där interna system som SAP och Service Configurator fungerade som datakällor och där målet var att bedöma skillnaderna mellan den planerade och faktiska användningen av reservdelar. Men på grund av olika prissättningsmodeller och kundbeteenden visade resultaten snabbt stora avvikelser, vilket gjorde kostnadsbaserade analyser opålitliga. Fokus skiftades då från kostnader till tekniska och operativa orsaker bakom det oplanerade underhållet.

Slutresultatet blev en strukturerad fyrstegsmodell. Den innehåller grundorsaker, avtalsspecifika omfattningar, kategorisering av händelser och förbättrad digital loggning via system som Salesforce och SAP. En mer konsekvent och datadriven förståelse för oplanerat underhåll möjliggörs av denna modell som samtidigt stödjer Wärtsiläs strävan efter digitalisering och kontinuerlig förbättring. Examensarbetet identifierar inte bara kritiska brister i dagens uppföljning och analys av oplanerade händelser utan presenterar även ett konkret förslag på förbättring. Även om slutsatserna baseras på ett begränsat urval av data, erbjuder modellen en skalbar lösning för att förbättra transparens, minska oplanerade kostnader och öka kundnöjdheten.

Språk: Engelska

Nyckelord: Livscykelavtal, oplanerat underhåll, reservdelar, Wärtsilä, underhållsplanering

Table of Contents

1	Introduction	1
1.1	Background	1
1.2	Purpose.....	2
1.3	Limitations	2
1.4	Disposition.....	3
2	Wärtsilä.....	4
2.1	Performance Services.....	4
3	Theory.....	6
3.1	Maintenance Management	6
3.1.1	Reliability Centered Maintenance (RCM)	7
3.1.2	Implementation and challenges of RCM in the Maritime Industry.....	8
3.2	Unplanned Maintenance	9
3.2.1	Unplanned Maintenance at Wärtsilä	10
3.3	Product Lifecycle Management	10
3.3.1	Application of Product Lifecycle Management in Maintenance.....	11
3.4	Wärtsilä Agreements.....	12
3.4.1	Optimized Maintenance Agreement (OMA).....	13
3.4.2	Guaranteed Asset Performance (GAP).....	13
3.4.3	Technical Management Agreement (TMA)	14
3.5	Spare Parts	14
3.5.1	Spare Parts in Marine	15
3.5.2	Spare Parts Used by Wärtsilä	16
4	Methodology.....	18
4.1	Quantitative Methodology Approach.....	18
4.2	Data Collection Methods	19
4.2.1	Preparations for the Comparison of Unplanned Maintenance	20
4.2.2	Interview for Practical Insight	21
5	Result	22
5.1	Data Collection Results	22
5.2	Interview Findings	25
5.3	A Framework for Consistent Unplanned Maintenance Evaluation.....	26
5.3.1	Event Categorization.....	27
5.3.2	Root Cause Categorization.....	28
5.3.3	Scope Definition Based on Agreement Type.....	28
5.3.4	Digital Logging Systems.....	29
6	Discussion	30

7	Conclusion.....	32
7.1	Further Research	34
8	Bibliography.....	35

Table of Figures

Figure 1	The bathtub curve (M. Smith & R. Hinchcliffe, 2003, p. 48)	7
Figure 2.	Main steps of the RCM approach (ABS 2004; Guedes Soares)	8
Figure 3.	The Conclusion Excel sheet.....	21
Figure 4.	Planned vs Actual fresh air filter cost per vessel.....	25
Figure 5.	Flowchart of the process.....	27

List of Tables

Table 1.	Comparison between the Marine contracts	13
Table 2.	Summary of the Vessels compared.....	22
Table 3.	Comparison of the contracts	23
Table 4.	Fresh air filter for 6 of the vessels.....	24
Table 5.	Step 1 of the method.....	27
Table 6.	Step 2 of the method.....	28
Table 7.	Step 3 of the method.....	28
Table 8.	Step 4 of the method.....	29

Appendix 1. Interview Questions

List Of Terms

Optimized Maintenance Agreement (OMA)

OMA is a formal agreement between Wärtsilä and a client, where Wärtsilä is responsible for the operations and maintenance of the client's assets. This type of contract typically outlines the scope of services, performance standards, responsibilities, duration, and financial terms. The goal of an OMA contract is to ensure that the assets are operated efficiently and maintained properly to maximize their performance and lifespan.

Guaranteed Asset Performance (GAP)

GAP is a type of service agreement where Wärtsilä guarantees specific performance metrics for the client's assets or equipment. These metrics can include efficiency, availability, reliability, and other key performance indicators (KPIs). The goal of a GAP contract is to ensure that the client's assets perform at optimal levels, providing predictable and reliable outcomes.

Technical Management Agreement (TMA)

TMA is an agreement where Wärtsilä is responsible for the technical management of a client's assets. This can include tasks such as monitoring and managing the technical performance, conducting regular inspections and maintenance, ensuring compliance with relevant regulations and standards and providing technical support and expertise. The contract typically outlines the scope of services, responsibilities of both parties, performance standards, duration, and financial terms. The goal of a TMA contract is to ensure that the client's assets are managed effectively and efficiently, maintaining their operational integrity and performance.

Service Configurator (SC)

The Service Configurator is a tool that enables the customization and configuration of service packages to meet individual customer needs, allowing for tailored maintenance plans, support services, and other service-related options.

Product Lifecycle Management (PLM)

A strategic approach for managing a product's entire lifecycle, from initial concept and design through manufacturing, maintenance, and disposal (Udroiu & Bere, 2019, p. 12).

Reliability Centered Maintenance (RCM)

A structured maintenance strategy that identifies and prioritizes maintenance tasks based on equipment reliability and the consequences of failures, aiming to ensure optimal performance and safety throughout the asset's lifecycle (B. Jones, 2011, p. 96).

1 Introduction

This thesis is written on behalf of the Maintenance Planning department at Wärtsilä. In this chapter, I will provide the background, define the purpose, outline the limitations and explain the structure of the thesis to facilitate better understanding.

1.1 Background

Wärtsilä serves customers through various types of agreements as well as transactional business for customers who do not have an agreement. The agreements on the marine side include TMA (Technical Management Agreement), OMA (Optimized Maintenance Agreement) and GAP (Guaranteed Asset Performance) in addition to non-agreement customers (transactional). One of the primary objectives of Wärtsilä's agreements, particularly those that include Maintenance Planning as a service (OMA, GAP, TMA) is to reduce unplanned costs. This is achieved by ensuring that maintenance is carried out efficiently and proactively, thereby minimizing unexpected breakdowns and associated expenses.

In the context of this report, "unplanned" refers to maintenance tasks or parts that are required outside of the standard maintenance schedule, such as parts breaking down earlier than expected. More specifically, this thesis considers two subcategories under the umbrella of unplanned maintenance with the first one being unscheduled maintenance, that is defined by maintenance that takes place during an overhaul or service event but was not originally planned to occur at that time. The component may have appeared in the maintenance plan for a later date but was replaced earlier due to condition or other findings.

The other subcategory is unplanned maintenance which is defined by interventions that are completely unexpected and not part of any current or future maintenance plan, these are typically caused by sudden equipment failure, operational misuse or unexpected wear and tear. Unplanned maintenance then results in unplanned costs for Wärtsilä.

1.2 Purpose

The primary purpose of this thesis is to determine how unplanned maintenance can be reliably compared between vessels under different Wärtsilä Lifecycle Agreements. It also aims to determine which type of Wärtsilä agreement has the most significant impact on unplanned parts consumption. By analyzing data from different agreements such as OMA, GAP and TMA. The study aims to determine which agreement type has the most significant effect on minimizing unplanned spare parts usage.

The thesis will also compare spare parts consumption between contract durations and transactional (non-contract) environments. By including data on engines operated without a maintenance contract, the study seeks to determine differences in failure rates, cost determinants as well as maintenance effectiveness overall.

The findings of the thesis will provide Wärtsilä with an insight that will allow them to rationalize its contracts, ensuring greater customer satisfaction and avoiding unexpected maintenance costs. The outcome can also prove to be beneficial in lowering the spares logistics as well as in forecasting and allowing the customers to be provided with the most cost-effective and reliable maintenance options.

To address the purpose of this thesis and guide the structure of the analysis, the following research questions were formulated:

1. How can unplanned maintenance events be reliably compared across Lifecycle Agreements?
2. What limitations arise when using cost-based data for such comparisons?

These questions reflect the practical challenges faced within Wärtsilä's maintenance planning function and frame the development of the analytical method proposed in this work.

1.3 Limitations

Despite the data collection and analysis processes being comprehensive and intended to ensure accuracy and dependability, several limitations were found that could impact on the value of the findings. These are noteworthy to mention since they put the findings into

context. Data used in the research are limited to customers who are ordering the spare parts exclusively through Wäartsilä. Third party vendors are automatically excluded. The results may not capture the whole market for the consumption of spare parts as well as unplanned maintenance behavior.

The analysis is limited to Vaasa Expertise Centre operating sites only. There is also one engine model in focus, W50. The findings apply a particular group of Wäartsilä's clients because the investigation does not cover other engine types or operating locations. The spare parts' consumption and maintenance performance may also vary when other engine models or operating sites with different management configurations are considered.

The analysis leaves out components with no standard maintenance interval. The assumption is made that only components with maintenance schedules are going to be included in the data. Nonstandard component failures, which might be the causes of unscheduled maintenance, are ruled out in the study. Spare part consumption over the contract term of Wäartsilä lifecycle agreements is the primary focus of this research. Data for the spare parts outside the contract term are added to allow for comparison. The parts are separated in a transactional way so that we can look at how the maintenance behavior changes when there is no contractual agreement. All these limitations should be considered when analyzing the results.

1.4 Disposition

The initial chapter provides an overview of the thesis, outlining the background, purpose, and limitations of the study. Following this, the subsequent chapter will focus on Wäartsilä, detailing the company's business operations and the specific business unit relevant to this thesis. The third chapter presents the theoretical framework, discussing the relevant theories that underpin the research. The fourth chapter describes the methodology, including the analysis of the data collection processes. The results of the thesis are presented in the fifth chapter. The sixth chapter is a discussion, and the final chapter offers a conclusion, providing the reader with insights derived from the research.

2 Wärtsilä

Wärtsilä is a global leader in innovative technologies and lifecycle solutions for the marine and energy markets. Their team of 17,800 professionals, located in over 280 locations across 79 countries, is dedicated to driving the decarbonization transformation in our industries worldwide. In 2024, Wärtsilä achieved net sales of EUR 6,4 billion. Wärtsilä is also listed on Nasdaq Helsinki (Wärtsilä, 2024) (Wärtsilä, 2025).

Wärtsilä was established in 1834 in Tohmajärvi as a sawmill company and has transformed into a big global company specializing in smart technologies and comprehensive lifecycle solutions for the marine and energy sectors. Throughout its history, Wärtsilä has broadened its scope through strategic acquisitions and innovations, evolving from conventional manufacturing to sophisticated engineering and technological solutions (Wärtsilä, 2024).

Today, Wärtsilä operates in over 70 countries, employing thousands of people worldwide. The company provides a wide range of products and services, including engines, power plants, marine propulsion systems, smart marine and energy solutions. Wärtsilä continues to drive advancements in technology to support the marine and energy industries, with a strong focus on sustainability and innovation (Wärtsilä, 2024).

2.1 Performance Services

Wärtsilä's Performance Services serve as a fundamental component of the company's extensive lifecycle solutions for the marine and energy sectors. These services are carefully crafted to enhance the performance, reliability, and efficiency of clients' assets which guarantees optimal operation throughout their entire lifecycle. The offerings under Wärtsilä's Performance Services include maintenance, upgrades, digital solutions and consultancy services (Wärtsilä, 2025).

One of the core internal functions within Performance Services is the Maintenance Planning department, which plays a central role in delivering Lifecycle Agreements. The Maintenance Planning team is responsible for the preparation, coordination, and optimization of maintenance activities for Wärtsilä-managed installations. This includes aligning service schedules with customer operations, ensuring that correct spare parts and

tools are available and creating planning documentation tailored to each specific vessel or installation. The team works closely with both internal systems (such as Service Configurator and SAP) and customer contacts to ensure that maintenance is timely, technically correct and contractually compliant. The function is essential for upholding the operational guarantees defined in Lifecycle Agreements.

Maintenance Services play a vital role in Wärtsilä's Performance Services, focusing on the optimal operation of engines, power plants and marine systems. To enhance the performance and efficiency of existing assets, Wärtsilä offers a range of upgrades and retrofits. Engine upgrades involve modernizing older engines with the latest technology to improve fuel efficiency, reduce emissions and increase reliability. System retrofits upgrade control systems, propulsion systems and other critical components to enhance overall performance and compliance with regulatory standards. Furthermore, hybrid solutions integrate hybrid technologies such as energy storage systems to optimize energy use and reduce environmental impact (Wärtsilä, 2025).

Customer support and training is another important role in Wärtsilä's Performance Services, facilitating the maximization of asset value for customers. The company offers continuous technical support to swiftly tackle any issues that may emerge, ensuring that operations experience minimal disruption. In addition, thorough training programs for customer personnel are designed to cover the operation, maintenance and troubleshooting of Wärtsilä's equipment and systems (Wärtsilä, 2025)

Wärtsilä's Performance Services have been successfully implemented in numerous projects worldwide, delivering significant benefits to customers. For instance, a shipping company achieved a 10% reduction in fuel consumption by implementing Wärtsilä's engine upgrades and digital solutions. A power plant operator reduced emissions by 20% through the installation of Wärtsilä's hybrid energy storage system and energy efficiency consultancy. Additionally, a marine operator improved vessel reliability and reduced unplanned downtime by 30% through Wärtsilä's condition-based maintenance and expert insight solutions (Wärtsilä, 2024).

3 Theory

In this chapter, I will review the relevant theories related to this thesis. These theories include maintenance and life cycle management, as well as contract and asset management.

3.1 Maintenance Management

Effective maintenance management is especially critical in high-end equipment-intensive sectors such as the shipping sector and the energy sector. Breakdowns can be avoided, the life of the assets can be extended, and the operating costs can be reduced with efficient maintenance planning (Lambert-Torres, Leandro Bonaldi, & Eli de Lacerda de Oliveira, 2020).

There are different types of maintenance strategies, which are generally classified into corrective, preventive, condition-based, and predictive maintenance with each playing a role in minimizing operational disruptions.

1. Corrective Maintenance is performed after a failure occurs. If repair is delayed, it is classified as deferred corrective maintenance and if done immediately, it is known as immediate corrective maintenance (Lambert-Torres et al., 2020).
2. Preventive Maintenance is on the other hand conducted at scheduled intervals based on either time criteria or usage-based criteria (Poljak, 2022).
3. Condition Based Maintenance (CBM) utilizes real time sensor data and diagnostics to assess asset health and detect early failure signs (Lambert-Torres et al., 2020).
4. Predictive Maintenance is a more advanced form of CBM that employs historical performance data and machine learning algorithms to forecast failures before they happen (Poljak, 2022).

Maintenance management is a critical aspect of asset lifecycle optimization and particularly in industries such as maritime, where unplanned downtime can result in significant financial losses (Poljak, 2022).

3.1.1 Reliability Centered Maintenance (RCM)

Reliability Centered Maintenance (RCM) is a maintenance strategy that is used to achieve maximum reliability, safety and cost effectiveness in the most important components of a machine. The main purpose of the RCM strategy is to determine and decrease failure modes and their combinations related to identified failure results in an effectively way (Karatuĝa, Arslanoĝlua, & Soaresb, 2023, pp. 237-238).

There is also some interesting history behind RCM. As the Industrial Revolution progressed, the people who designed and constructed machines also maintained them while basing their decisions on direct experience to prevent problems. With the expansion in industries and more functional specialization, maintenance decisions became less experienced dependent and formalized.

By the middle of the 20th century, reliability engineering had evolved the "bathtub curve" failure mode where there were three periods of failures: early (infant mortality), steady (random failures) and late (wear-out). This formed the basis for planned overhauls before the wear out period. More recent studies, particularly in aviation, established that most failures happened randomly and that the traditional overhaul-based maintenance was not only inefficient but even detrimental. All of this led to more data-driven and condition-based maintenance (M. Smith & R. Hinchcliffe, 2003).

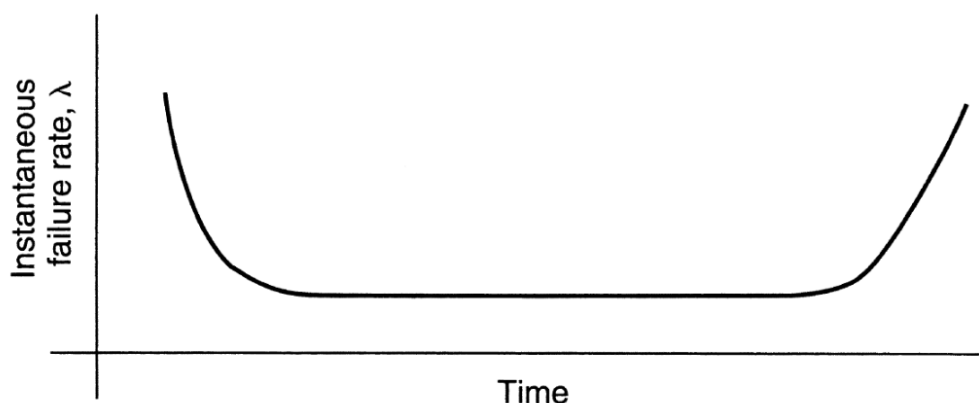


Figure 1 The bathtub curve (M. Smith & R. Hinchcliffe, 2003, p. 48)

As illustrated in Figure 1, the bathtub curve is a widely used model for describing the failure rate of components over time. Research within the aviation industry questioned the assumption that most components fall into the control domain of the bathtub curve. United Airlines, the US Navy and other research found that only a relatively minor fraction

of components showed a predictable wear-out cycle. Most failures proved to be random in nature and planned overhauls did not necessarily prevent breakdown. These findings had big effects on maintenance policy, requiring condition-based maintenance rather than regular overhauls (M. Smith & R. Hinchcliffe, 2003). Figure 2 below is an excellent example that presents the steps for a successful RCM strategy according to Guedes Soares.

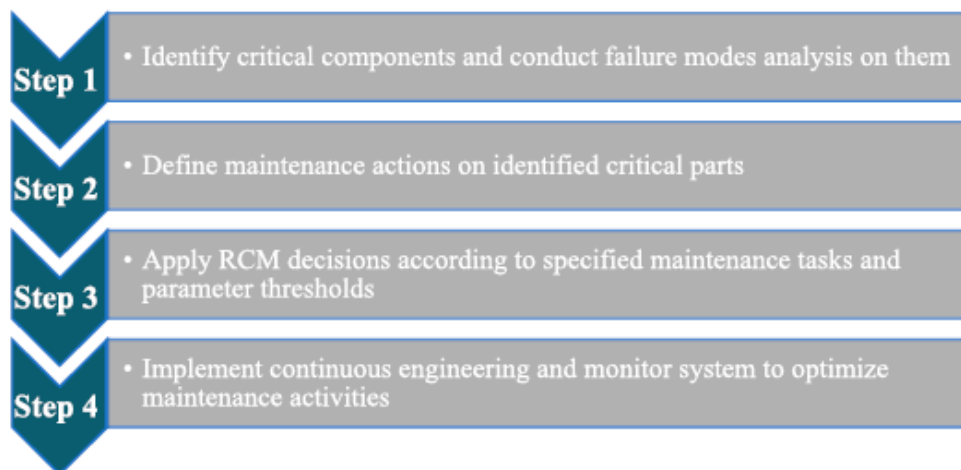


Figure 2. Main steps of the RCM approach (ABS 2004; Guedes Soares)

3.1.2 Implementation and challenges of RCM in the Maritime Industry

In the maritime industry, RCM works as a tool to increase the safety and reliability of vessel operation. Application of RCM to vessel operations is confronted with unique challenges including resource constraints and expert knowledge demands. An RCM analysis of ship operations found that though RCM was generally regarded as resource-intensive, the project could be made viable beginning with key systems. The analysis also proposed the utilization of a subjective qualitative approach to sidestep constraints with traditional decision techniques and needs for large failure data (Tripathi & Prasad , 2024).

Despite the recognized advantages, the application of RCM in maritime operations is often confronted with diverse special challenges. Restricted availability of resources that includes a restricted budget, available time and skilled workforce. This is particularly regarding the strict and comprehensive RCM process (M. Smith & R. Hinchcliffe, 2003). These obstacles demand careful planning and prioritization of the implementation process, that is done by maritime operations staff. For example, Tripathi and Prasad suggest that the adoption of an effective RCM methodology in maritime operations should commence with the vital

vessel systems, for example, propulsion, navigation and communications systems that have direct effects on the safety of vessels and operation integrity (Tripathi & Prasad , 2024).

One major challenge lies with the intensive resource process that involves specialist expertise, data handling and specially trained personnel. Most organizations lack the resources required, including limited budgets. The answer lies with the prioritization of essential systems and phase-by-phase implementation of RCM rather than putting it into all the equipment at the same time (M. Smith & R. Hinchcliffe, 2003).

Another challenge within RCM is that it is not a universal solution for every company. RCM does not necessarily result in immediate cost savings or reliability gains. The success of RCM relies on a few factors such as system complexity, quality of failure data and management support. In the absence of management support, RCM projects tend to fail or are not sustainable. Many companies will also struggle to implement RCM due to the lack of historical failure data. Most organizations are not well documented with equipment failure data and that makes it hard to perform failure mode and effects analysis (FMEA) effectively. Failure definitions also vary across different industries and that makes standardization of classification of failure difficult (B. Jones, 2011, pp. 97-99).

3.2 Unplanned Maintenance

Unplanned maintenance refers to a form of maintenance that is not planned ahead of time but is performed due to unexpected equipment failure or faults. In contrast to preventive or predictive maintenance, which is planned and aimed at reducing downtime, unplanned maintenance is reactive maintenance that will always cost more and cause operational delays. This will lead to having less asset availability (Mobley, 2002, pp. 24-26).

In industries like energy and maritime, unscheduled maintenance can have serious consequences. Equipment breakdowns at sea can result in expensive delays, safety issues and logistical challenges when it comes to the transportation of spare parts. According to Mobley failure records and downtime expenses are frequently not adequately documented. Many businesses find it difficult to estimate the financial effect of such failures. As a result, budget justification becomes challenging and particularly in organizations where maintenance is only seen as a cost center even when the technical need for predictive tools is evident (Mobley, 2002, pp. 24-29).

According to Jones the lack of strategic coherence in asset management is frequently reflected in high rates of unscheduled maintenance. Businesses become stuck in reactive cycles and pay avoidable expenses in the absence of proactive lifecycle planning, cross-functional cooperation and a more structured failure data. Jones contends that to lessen the unpredictability and business impact of unplanned failures, a change toward risk-based and reliability-centered solutions is necessary (B. Jones, 2011, pp. 96-100).

3.2.1 Unplanned Maintenance at Wärtsilä

To understand the thesis, it is essential to align the definition of unplanned maintenance with Wärtsilä's internal practices and risk management frameworks. According to internal documentation and process materials from Wärtsilä, unplanned maintenance can be broken down into several distinct categories.

- Condition-based maintenance materials: Parts replaced due to condition assessments, sometimes linked to extended intervals.
- Unscheduled maintenance materials: Parts replaced during overhauls but were not originally planned at that stage.
- Unplanned maintenance materials: Parts replaced due to unexpected operational or quality issues.
- Consumables and spares: Customer-accessible materials under unplanned budget allocations.

3.3 Product Lifecycle Management

Product Lifecycle Management (PLM) is a comprehensive system designed to consolidate and oversee various types of information, processes and personnel from multiple domains. Turning it into an end-to-end strategy for product development. This system digitizes and organizes all essential data and activities. The distinct stages of product development enable stakeholders to clarify objectives, provide meaningful insights, generate deliverables and ultimately enhance the competitive edge of the product (Krebsbach, 2025).

The beginning of PLM is often referred to in 1957 when the advertising firm Booz Allen Hamilton used the five-step cycle that mapped a product's whole life cycle, from beginning to retirement. PLM has evolved over time, but the primary goal has always been to gain a competitive advantage and speed in product development. Today PLM is more focused on centralized information and different data management. The system offers a systematic way of managing information. Issues can be resolved faster, and the overall cost of products can be reduced (Krebsbach, 2025).

The fundamental principles of PLM include Centralized Data Management that underscores the necessity of consolidating all product-related data in a singular, easily accessible storage. This approach guarantees that all stakeholders engaged in the product lifecycle can access consistent and current information. The second principle of PLM is Process Standardization, PLM supports the correlation of processes throughout every phase of the product lifecycle. This standardization improves operational efficiency, minimizes errors and fosters consistency throughout the product lifecycle (Krebsbach, 2025).

Collaboration is the third principle of PLM that encourages cooperative efforts among various teams and departments that are involved in the product lifecycle. This collaboration is essential for dismantling organizational problems and enhancing communication between all teams. Lifecycle Perspective is also affected by PLM, it adopts a comprehensive perspective on the product lifecycle considering all phases from design to decommissioning. This holistic view ensures that decisions made in one phase do not adversely affect other phases of the life cycle (Krebsbach, 2025).

3.3.1 Application of Product Lifecycle Management in Maintenance

PLM is essential for improving maintenance plans in a variety of areas, such as manufacturing and the maritime industry. One of the most significant advancements in PLM is the use of Big Data analytics to enhance maintenance decision making. The framework outlines a structured approach using real-time data acquisition, predictive modelling and digital twin technology in maintenance planning (Zhang, Ren, Sakao, & Huisinigh, 2017, pp. 229-240).

There are also problems when implementing PLM and one of them is the huge amount of unstructured data at various lifecycle stages such as manufacturing, operation and end

stage. Big Data analytics is responsible for the transformation of raw data into valuable information. That means a big data-driven PLM approach for data acquisition, storage, process and predictive analytics is key for the optimization of maintenance planning (Zhang, Ren, Sakao, & Huisingh, 2017).

Another problem when implementing PLM is handling information flows between maintenance environments and different phases of the life cycle. Companies are generally effective in handling information flows at initial phases like manufacturing and design but fail to do so at the maintenance and usage stage. That results in no feedback to production and design phases. Such a lack of feedback loops limits design and production development possible through maintenance operations (Udroiu & Bere, 2019, pp. 76-77).

One of the more impactful applications of PLM in maintenance is real-time condition monitoring. It helps to monitor equipment health and predict failures prior to their occurrence, it is most relevant in marine and energy sectors whose untimely shutdowns can lead to catastrophic financial losses. The shift from reactive to predictive maintenance enhances the operating efficiency as the maintenance is planned in actual asset conditions and not in fixed time intervals. According to their studies, IoT-enabled PLM solutions cut unplanned downtime in mission-critical infrastructure environments by up to 30% (Abdul, et al., 2020, pp. 140-144).

3.4 Wärtasilä Agreements

Wärtasilä provides a variety of Lifecycle Agreements aimed at enhancing the performance, reliability and efficiency of assets within the marine and energy industries. These agreements deliver organized support to customers by facilitating effective maintenance planning, technical oversight and performance enhancement throughout the duration of the asset's life. Wärtasilä's Lifecycle Agreements offer different levels of assistance based on customer needs. The three main categories of Marine agreements include Optimized Maintenance Agreement (OMA), Guaranteed Asset Performance (GAP), and Technical Management Agreement (TMA) (Blenkey, 2016). Table 1 below explains the differences between the contracts in an easy way.

Table 1. Comparison between the Marine contracts

Category	OMA	GAP	TMA
Objective	Improve cost predictability and availability	Ensure reliability and availability	Provide technical support and management
Key Features	Data-driven, Predictive maintenance, Proactive support	Performance guarantees, Remote support, Predictive intelligence	Technical support, Remote troubleshooting, Flexible planning
Benefits	Cost predictability, Enhanced availability, Reduced unplanned maintenance	Maximized uptime, High efficiency, Cost predictability	Optimal performance, Reduced downtime, Expert support

3.4.1 Optimized Maintenance Agreement (OMA)

The OMA contract prioritizes preventive maintenance planning and execution to ensure that marine and energy assets operate efficiently with a reduced risk of unexpected failures. This agreement offers scheduled maintenance services, original equipment manufacturer (OEM) spare parts and technical support. Everything is designed to minimize unplanned downtime and improve equipment longevity. With Wärtsilä's OMA, customers are also provided with expert insights on maintenance intervals, effectively preventing unnecessary operational disruptions and optimizing lifecycle costs (Wärtsilä, 2025, pp. 41-48).

One significant benefit of OMA is the ability to forecast maintenance expenses accurately. By strategically planning service tasks and component replacements, asset owners can reduce the financial risks linked to unexpected repairs. Furthermore, Wärtsilä's comprehensive data on engine performance allows for the recommendation of maintenance procedures that are tailored to actual operational conditions. Rather than sticking to predetermined schedules, thereby enhancing asset reliability and length of life (Wärtsilä, 2025, pp. 41-48).

3.4.2 Guaranteed Asset Performance (GAP)

The GAP agreement is a performance-oriented contract in which Wärtsilä offers assurances regarding specific operational metrics. These include fuel efficiency, emissions reduction and overall system reliability. Unlike the OMA, which is mainly concerned with maintenance scheduling, the GAP agreement requires Wärtsilä to actively oversee and improve the performance of the customer's assets to fulfil predetermined performance standards (Wärtsilä, 2025).

A key aspect of the GAP agreement is the implementation of digital technologies for real-time monitoring of asset conditions. Wäartsilä utilizes remote monitoring, artificial intelligence (AI) diagnostics, predictive analytics and they take proactive measures to prevent potential issues. By offering performance guarantees, Wäartsilä assumes a portion of the operational risks alongside its customers, providing financial incentives should the agreed performance standards not be achieved. This approach encourages transparency and promotes ongoing enhancements in performance (Wäartsilä, 2025).

3.4.3 Technical Management Agreement (TMA)

The TMA contract provides a complete suite of technical support services for customers that includes maintenance planning, spare parts management and troubleshooting assistance. In contrast to the OMA and GAP agreements that emphasize maintenance and performance guarantees, the TMA is specifically aimed at ensuring smooth daily technical operations for those customers who prefer to entrust their asset management responsibilities to the professionals at Wäartsilä (Wäartsilä, 2025, pp. 41-48)

The TMA contract assumes the responsibility for formulating and implementing maintenance strategies, which embrace inventory optimization and condition-based maintenance planning. This arrangement allows customers to leverage Wäartsilä's technical proficiency, thereby minimizing the necessity for internal engineering resources. Additionally, the agreement provides access to Wäartsilä's extensive global service network, assisting in prompt response times for technical assistance and spare part deliveries (Wäartsilä, 2025, pp. 41-48).

3.5 Spare Parts

The term spare part refers to a component, sub-unit or a major assembly that is available in stock for replacement when necessary. A typical example of a spare part is the spare wheel provided with two or four-wheeled vehicles, which can be used in the case of a tire puncture. Spare parts are stored to substitute identical or similar components when the original part fails or deteriorates. Certain spare parts can be offered as tools or accessories essential for conducting repairs and replacing defective parts, such as the jack and tool kit included with vehicles (K.Shridhara, 2008).

Accurate spare part identification is a crucial component of spare parts management at sea. To ensure accurate possession, every component on a vessel has a unique identification code, such as a part number, drawing number or material number. Misidentification of parts can result in expensive delays and operating inefficiencies because many marine engines and auxiliary systems are highly specialized. To lower the chance of buying the wrong parts, ship operators rely on thorough technical documentation and maintenance logs to keep an accurate database of spare parts (Somani, 2021).

Maintenance agreements are essential for controlling the use of spare components. The U.S. Navy's experience with unscheduled maintenance is a great example that emphasizes how crucial it is to comprehend ship conditions prior to organizing repairs. Navy vessels routinely operate globally, requiring consistent access to necessary spare parts to maintain continuous operational readiness. This means that the U.S. Navy must manage spare parts with precision to prevent significant unplanned work, which typically increases operational costs and leads to schedule delays.

Insufficient vessel state frequently results in significant unplanned work, which raises costs and delays schedules. These difficulties can be learned by putting in place thorough maintenance agreements that incorporate frequent evaluations and data gathering. This will guarantee the timely delivery of required spare parts and cut down on unscheduled maintenance (Mouschoutzi & T.Ponis, 2022, pp. 71-83).

3.5.1 Spare Parts in Marine

The maritime industry faces several challenges in spare parts logistics, moving assets that need spare parts delivered to various places across the world and roughly 3,000 distinct ports. Geographically, supply and demand are scattered with China, South Korea and Japan providing a significant share of spare parts. There are also strict deadlines for port deliveries, which can be crucial considering possible cost overruns. Numerous parties which include shipping firms, asset managers and logistics providers are involved in the logistics network. The logistic network raises prices, complexity and uncertainty. An estimated 25–35% of operating costs can be attributed to maintenance activities (Mouschoutzi & T.Ponis, 2022, pp. 71-72).

The goal of effective spare parts logistics strategies is to maximize availability at affordable prices. Repair by replacement is a popular strategy that involves swapping out nonfunctioning parts for working ones. Another strategy to cut down time is to stock on board, although this can result in space constraints and capital commitments. Spare parts can be classified as consumables, which are thrown away after use. They can also be classified as repairable which then includes reverse logistics (Mouschoutzi & T.Ponis, 2022, pp. 71-72).

For ships that operate all over the world, the logistics network's structure is very important. Cost-cutting measures like inventory pooling and lateral transshipment are examples of flexibility possibilities. Planning for transportation and selecting a form of transportation are also crucial considerations. Aspects like inventory control and demand forecasting are combined in integrated models (Mouschoutzi & T.Ponis, 2022, pp. 75-76).

Additive manufacturing (AM) has the potential to transform the spare parts supply chain through local and on-demand production, which can lead to shorter delivery times, lower transport costs and reduced inventory. AM also enables the production of expired or specially adapted parts. The technology is still in development and requires further research to succeed in the marine industry (Mouschoutzi & T.Ponis, 2022, p. 81).

3.5.2 Spare Parts Used by Wärtsilä

Critical spare parts are essential components that ensure the continuous operation of Wärtsilä engines and power systems. Failure of these components leads to immediate breakdown in operations and that is why Wärtsilä take top priority in spare parts planning. The spare parts can be divided into Critical spare parts, non-critical spare parts and long lead time parts. Critical Spare parts are the top priority in spare parts planning for Wärtsilä. The reason is that the failure of these leads to immediate operational downtime. An example of a critical spare part is Cylinder heads. They are essential for engine performance and a subject to high stress, leading to potential cracks and failures (Wärtsilä, 2025) (Wärtsilä, 2024).

Non-Critical spare parts are also a big part of the spare parts planning. These parts ensure component integrity and they prevent progressive damage. A few examples are filters, seals, gaskets, belts and hoses. Wärtsilä's approach to these parts are that they offer

preventative maintenance kits that contain these parts. Long lead-time parts are often part of a more complex supply chain or in a limited production facility. That means it is a bit different compared to the other parts. Examples of these parts include Crankshafts, Cylinder blocks and Camshafts. Wärtsilä manages these by standardizing replacement components for these engines. (Wärtsilä, 2025) (Wärtsilä, 2024). Together, the concepts introduced in this theory chapter form the basis for understanding the challenges in comparing unplanned maintenance and justifying the need for a structured analysis method.

4 Methodology

This chapter will include a thorough overview of the methodologies that have been used in the construction of this thesis, and a clear description regarding how each methodology has been utilized. The methodologies that are described and analyzed in this chapter include a quantitative approach, which will be described in detail in relation to the actual techniques and processes that were utilized in the gathering of data relevant to this thesis. There was also a semi-structured interview conducted to strengthen the data.

4.1 Quantitative Methodology Approach

The approach used in this thesis is a Quantitative methodology to investigate how Wäartsilä's Lifecycle Agreements affect the use of spare parts and unscheduled maintenance. It makes sense to choose a quantitative approach since it enables objective, quantifiable examination of failure rates, cost effectiveness and maintenance performance metrics. This method ensures reliability and removes subjective biases that can occur in qualitative investigations by examining structured datasets (Bryman, 2012, ss. 35-36).

Using a cross-sectional approach, the study gathers past maintenance data at a particular moment in time. Finding trends and connections in the utilization of spare parts and maintenance performance across various agreement types. Bryman asserts that cross-sectional studies are ideal for investigations that use statistical analysis to determine correlations between variables. The variables in this instance are the frequency of failures, cost of maintenance, use of spare parts and the type of agreement (OMA, GAP, TMA) (Bryman, 2012, ss. 59-61).

By adopting a quantitative research approach, this study ensures internal validity and reliability by relying on structured datasets rather than subjective assessments. Bryman emphasizes that structured data collection, when applied strictly, enhances the replicability of research findings. This is particularly relevant in industrial settings where maintenance decision making is based on data-driven insights rather than qualitative interactions (Bryman, 2012, ss. 160-165).

4.2 Data Collection Methods

This section outlines the methods used to collect and compare data. The objective is to identify discrepancies and ensure data consistency across different systems. This will be done by a testing approach to evaluate whether it is possible to compare unplanned maintenance between two tracking systems.

The Service Configurator (SC) and SAP were selected as the primary sources of data for this study, because they are two of the most significant maintenance tracking systems in Wärtsilä's operations and they record different but complementary aspects of maintenance activity. By comparing and analysing data from these two systems, this study attempts to determine whether unplanned maintenance trends can be identified and analysed effectively.

The Service Configurator is a maintenance planning and management system used to coordinate maintenance activities on a contracting basis within Wärtsilä. It is primarily used to assist lifecycle agreements, maintenance planning and execution of services on engines and other critical machinery. In total, cost-based comparisons were initially performed on a larger set of vessels. However, only a subset of nine vessels is presented in this thesis as they were sufficient to illustrate the inconsistency and limitations of cost-based analysis. The broader dataset was used internally to confirm that the patterns observed were consistent across different agreement types and operating conditions.

The Service Configurator lists that are used for this thesis contain detailed information about the configurations of various vessel engines. It has important columns such as Part Number, Description, Quantity and Total Value in Euro. The service configurator is also used to track the individual configurations and parts of each engine, providing a detailed description of the equipment used.

SAP (Systems, Applications, and Products in Data Processing) is an enterprise resource planning system implemented by Wärtsilä and other international companies to centralize business processes like financing, logistics, purchasing and maintenance tracking. SAP serves as the main system for tracking spare parts and maintenance work orders in Wärtsilä. The SAP list provides a list of what the customer ordered for their vessels,

including Part code and Quantity. It is used to validate the correctness of the service configurator data in this thesis.

4.2.1 Preparations for the Comparison of Unplanned Maintenance

Service configurator and SAP are two primary databases that are used for tracking maintenance activities. However, unplanned maintenance events are not always easy to categorize, making direct analysis difficult. The vessel data was first retrieved from SAP and SC, then cleaned to eliminate any duplicates, manage missing values and standardize formats. Missing values were either filled in with appropriate data or excluded from analysis. Standardizing formats involved all data entries being transferred into an Excel spreadsheet with the same format. These were all crucial steps for guaranteeing the integrity and uniformity of the data. Data from the SAP lists and the service configurator lists were integrated into one data set with the relevant columns only. This involved matching columns and ensuring that the data from the two sources could be compared directly.

The transformation process was conducted manually in Excel. First, the SC data was transferred into the SC sheet, and the SAP data was transferred into the SAP sheet in Excel. All vessels had over 500 parts ordered so it was necessary to create a conclusion sheet to contrast and compare data from both SAP and SC. The sheet had columns for spare part number, required quantity, cost total, price per part, customer used parts, cost total for actual used parts, parts usage difference, actual cost and a parts description.

Various calculations were performed to obtain comparisons of the data and to identify the differences. For example, Cost total was calculated through multiplying Required Quantity by Price per part, and Cost Total for actual used parts was calculated through multiplying Customer used parts by Price per part. To find the actual cost, the cost total was subtracted from the Cost Total for actual used parts. Contrasts and comparisons were highlighted to provide a clear overview of any differences and key values. Below is Figure 3 which shows how the conclusion sheets turned out without SPN numbers since those are confidential.

Req quantity	Cost total	Price per part	Customer used parts	Cost with current price	Used parts - Required parts	Actual Cost	Description Name
16	€64	€4	24	€96	8	€32	Cylindrical pin
132	€330	€3	48	€120	-84	-€210	O-ring
78	€195	€3	186	€465	108	€270	O-ring
408	€7 793	€19	320	€6 112	-88	-€1 681	O-ring
18	€21 294	€1 183	47	€55 601	29	€34 307	Main bearing shell (upper)
18	€21 294	€1 183	40	€47 320	22	€26 026	Main bearing shell (lower)
102	€67 116	€658	57	€37 506	-45	-€29 610	Antipolishing ring
72	€13 392	€186	198	€36 828	126	€23 436	O-ring
16	€18 320	€1 145	24	€27 480	8	€9 160	Thrust bearing half
8	€10 104	€1 263	14	€17 682	6	€7 578	Bearing shell
10	€10 070	€1 007	16	€16 112	6	€6 042	Bearing bush
88	€7 436	€85	75	€6 338	-13	-€1 099	Gasket set
22	€444	€20	16	€323	-6	-€121	Hose gasket
4	€138	€34	1	€34	-3	-€103	O-ring
172	€6 656	€39	73	€2 825	-99	-€3 831	Hose gasket
95	€2 290	€24	0	€0	-95	-€2 290	O-ring
24	€562	€23	4	€94	-20	-€468	Hose gasket
616	€2 352	€4	688	€2 627	72	€275	O-ring
4	€2 444	€611	1	€611	-3	-€1 833	V-ring
84	€4 166	€50	0	€0	-84	-€4 166	Hose Gasket
47	€56 353	€1 199	106	€127 094	59	€70 741	Shim
36	€65 160	€1 810	25	€45 250	-11	-€19 910	Bearing bush
47	€110 372	€2 348	95	€223 092	48	€112 720	Big end bearing kit
144	€15 408	€107	236	€25 252	92	€9 844	Screw
72	€4 608	€64	88	€5 632	16	€1 024	Securing ring
102	€323 442	€3 171	57	€180 747	-45	-€142 695	Piston ring set
144	€5 746	€40	40	€1 596	-104	-€4 150	Sleeve
47	€2 298	€49	115	€5 624	68	€3 325	O-ring
144	€5 371	€37	60	€2 238	-84	-€3 133	Nut

Figure 3. The Conclusion Excel sheet

4.2.2 Interview for Practical Insight

In addition to the quantitative analysis and review of internal Wärtsilä documentation, a semi-structured interview was conducted with a colleague who works as a Senior Technical Quality Manager within Wärtsilä. The interview was conducted to obtain practical knowledge about the way unplanned maintenance is currently defined, monitored and perceived internally. It consisted of eight questions and the results are used to support the analysis and are summarized in the results and discussion chapters. The full list of interview questions is available in Appendix 1. The interview represents one view of the unplanned maintenance and may not capture all viewpoints across Wärtsilä.

5 Result

In this chapter, the results of comparing unplanned maintenance on nine vessels operating on three kinds of Wärtsilä contracts GAP, OMA and TMA are presented. The main goal of the research was to compare the effect of different lifecycle agreements on the frequency and type of unplanned maintenance activities.

5.1 Data Collection Results

Although this thesis shows detailed results from nine selected vessels, the same cost-based method was applied to a broader group of vessels during the initial analysis phase. The nine presented vessels were selected because they clearly demonstrated the core issue that cost data, due to its variability, is not a reliable basis for comparing unplanned maintenance across agreements. The investigation demonstrated a wide cost variance compared to budgeting for planned maintenance. As presented in Table 2 there are big differences in Actual cost between the vessels.

Table 2. Summary of the Vessels compared

Vessel	Contract Type	Actual Cost
Vessel A	GAP W50	€ 328 001
Vessel B	GAP W50	€ 621 955
Vessel C	GAP W50	€ 582 849
Vessel D	TMA W50	-€ 1 545 790
Vessel E	TMA W50	€ 4 384 851
Vessel F	TMA W50	-€ 1 641 524
Vessel G	OMA W50	-€ 135 495
Vessel H	OMA W50	€ 121 356
Vessel I	OMA W50	-€ 2 343 112

The results show considerable variability in the unplanned maintenance between vessels. Surprisingly, significant negative deviations for certain vessels were recorded under the TMA agreement (e.g., Vessel D at €-1,545,790 and Vessel F at €-1,641,524). Positive numbers indicate that maintenance costs turned out to be higher than planned, meaning that the customer ordered more parts than originally planned. Negative numbers indicate that customers purchased fewer spare parts than initially planned for and costs were lower than planned. This variation in maintenance costs is largely from Wärtsilä's inconsistent

application of pricing discounts, which depend on customer relationships and negotiated terms. As a result, these discrepancies undermine both the comparability and validity of the maintenance cost analysis.

Table 3. Comparison of the contracts

Contract Type	Number of Vessels	Average Actual Cost	Range (min – max)
GAP	3	€ 511 000	€328 001 – €621 955
OMA	3	-€785 750	-€2,343 112 – €121 356
TMA	3	€ 399 000	-€1,641 524 – €4,384 851

If we look at Table 3, we can see the differences between the contracts. The GAP contracts consistently show positive actual costs, meaning more parts were consumed than originally planned. This may reflect the higher monitoring and performance guarantee obligations under GAP which often result in more proactive or preventive interventions. OMA contracts show a negative average actual cost, indicating fewer parts were consumed than planned. Strong preventive planning and the fact that customers frequently decide to avoid some replacements or buy parts outside of the contract may be the cause of this. TMA contracts show the greatest variation in cost outcomes. This suggests more reactive maintenance behavior where some vessels may heavily exceed budgets while others use fewer parts than expected, depending on crew actions and technical oversight which is hard to predict. This variation in financial outcomes across agreement types illustrates the complexity of comparing unplanned maintenance based solely on cost.

Table 4. Fresh air filter for 6 of the vessels

Vessel Name	Contract Type	Description Name	Planned Quantity	Actual Quantity	Planned Cost	Actual Cost
Vessel A	GAP W50	Fresh air filter	150	57	€ 3 585	-€ 2 223
Vessel B	GAP W50	Fresh air filter	126	75	€ 3 011	-€ 1 219
Vessel C	OMA W50	Fresh air filter	256	182	€ 6 118	-€ 1 769
Vessel D	OMA W50	Fresh air filter	336	66	€ 8 030	-€ 6 453
Vessel E	TMA W50	Fresh air filter	202	52	€ 11 445	-€ 9 635
Vessel F	TMA W50	Fresh air filter	312	68	€ 7 456	-€ 5 832

If we take a deep dive into the data and look at a part like fresh air filter, Table 4 shows the cost difference between planned and actual fresh air filter consumption on some vessels. While Vessel B shows an okay alignment, Vessel E exceeded planned costs significantly. This variation illustrates the inconsistency in cost-based comparison, which led to the conclusion that this type of data is not reliable enough for evaluating unplanned maintenance.

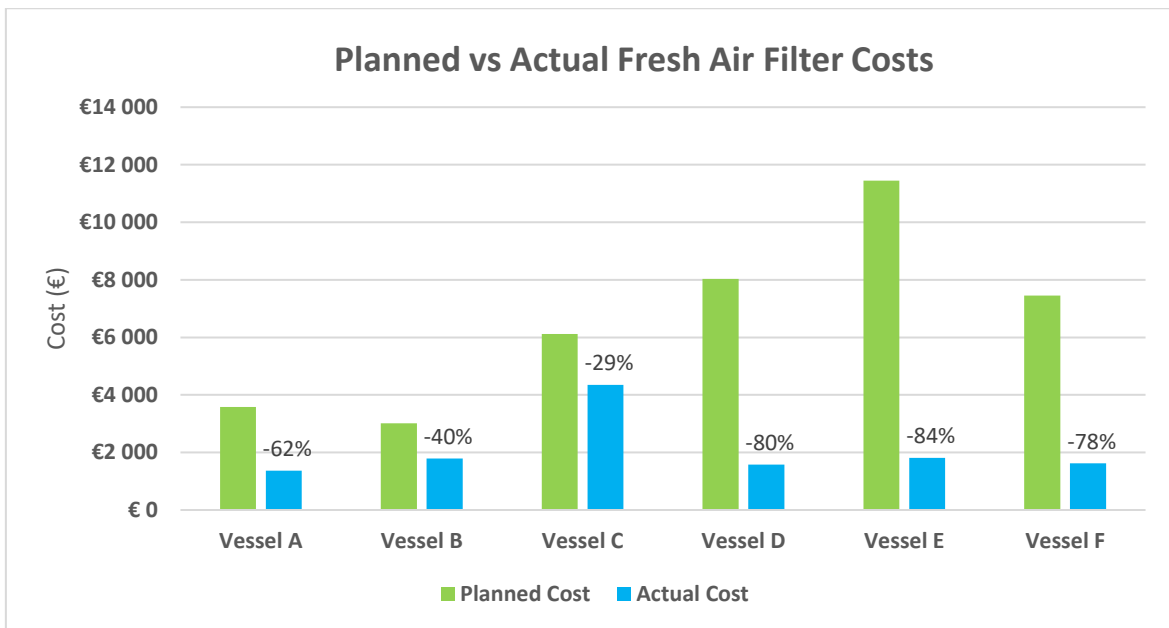


Figure 4. Planned vs Actual fresh air filter cost per vessel

Figure 4 illustrates the planned and actual spare part costs for fresh air filters across six vessels. In all cases, the actual costs were significantly lower than planned, with deviations ranging from -29% to -84% . This suggests that cost data alone does not provide a reliable basis for analyzing unplanned maintenance, as the planned costs are often inflated or adjusted based on contractual pricing structures, spare part buffers, or customer-specific discounts. This finding underscores the limitation of applying cost-based comparison across a broader dataset, such as 60 vessels. These inconsistencies support the shift toward an event-based analysis method.

5.2 Interview Findings

To gain further insight into how unplanned maintenance is currently understood and managed within Wärtsilä, a semi-structured interview was conducted with a colleague working as a Senior Technical Quality Manager. The interviewee has direct experience with development projects that involve tracking unplanned maintenance, including cases of premature wear and failures outside scheduled intervals.

According to the interviewee, the most common causes of unplanned maintenance are either operational or quality-related issues. These can be further broken down into subcategories, such as design and manufacturing under quality and fluid management

under operational. They also emphasized that the term “unplanned maintenance” is frequently used but poorly defined within the company.

The interview also confirmed several findings from the data analysis. For instance, the interviewee highlighted that there is no standardized system currently in place for logging unplanned events although development efforts are ongoing with system implementation planned for the coming year. They also noted that contract types like TMA and GAP influence how unplanned events are handled, and that the TMA contract is easier to manage internally, despite not always improving customer satisfaction. This is consistent with what I found while writing the thesis.

Finally, the interviewee thought that digital tools like Salesforce and SAP offer potential for improving traceability but only if customers consistently provide correct metadata. They also pointed out that extending maintenance intervals too far can lead to misclassified failures that appear as “unplanned,” when in fact they may be a result of deferred scheduled work. This is also something that I found when doing the data collection.

5.3 A Framework for Consistent Unplanned Maintenance Evaluation

Due to the limitations in the initial comparison, primarily caused by inconsistent pricing discounts across customers. I needed to explore alternative methodologies for assessing and comparing unplanned maintenance. The findings in the thesis led to a deeper investigation into Wärtsilä’s internal practices and definitions related to unplanned maintenance. Through the review of internal documentation and operational insights, it became clear that the current way of evaluating unplanned maintenance within performance services lacks standardization and is often based on unstructured Excel files and email chains. This results in inefficiencies and limits the organization’s ability to conduct proper root cause analysis or quality improvement actions. A more structured method for comparing unplanned maintenance could be based on Wärtsilä’s own internal categories and insights and look something like Figure 5.

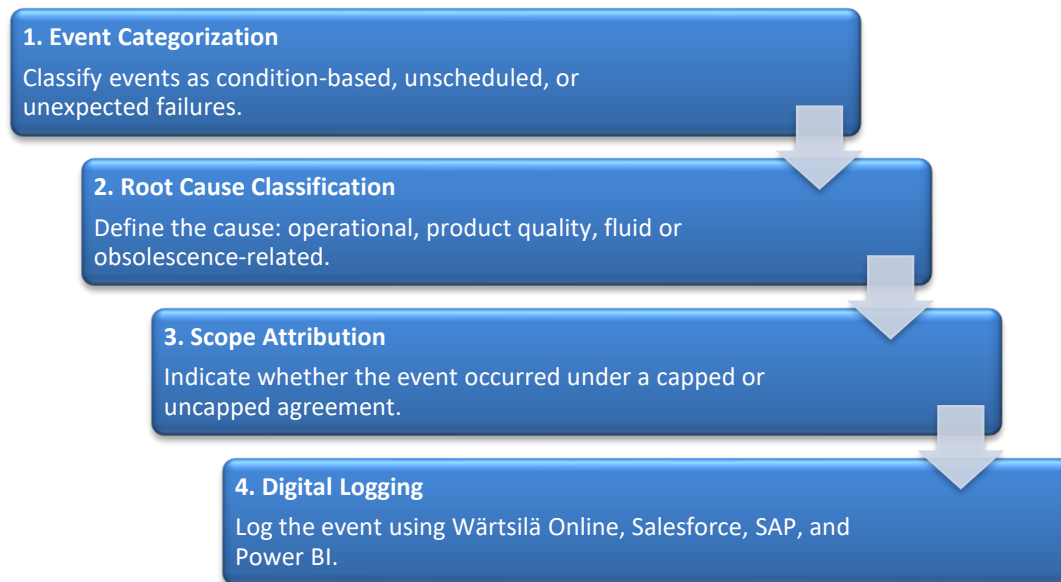


Figure 5. Flowchart of the process

Figure 5 shows the methodology for comparing unplanned maintenance that was developed during the work. The four steps include categorizing maintenance events, identifying root causes, scope attribution and structured digital logging via the company's own systems. The steps enable a more consistently informed and transparent comparison between vessels and contract types. The four-step method developed in this thesis could be integrated into Wärtsilä's planned digital tools. This would enable automatic reporting on unplanned maintenance patterns across contracts and a better comparison between the vessels. I will be discussing the steps in a more detailed way in the following chapters.

5.3.1 Event Categorization

Through internal documentation, Wärtsilä identifies several types of events that fall under the unplanned maintenance category. These event types go beyond cost and reflect operational reality.

Table 5. Step 1 of the method

Category	Description
Condition-based replacements	Parts replaced due to engine condition (outside fixed interval).
Unscheduled component replacements	Components changed during overhauls but were not originally planned to be replaced.
Unexpected failures	Failures caused by operational or product quality issues.

Table 5 illustrates the three primary categories employed internally by Wärtsilä to classify unplanned maintenance events. They are based on the type of intervention and not the cost outcome. The aim is to have a more operationally driven basis for the definition and analysis of unplanned maintenance activities across different vessel agreements. By focusing on the type of maintenance event rather than its cost, the analysis becomes more reliable and comparable across different vessels and contract types.

5.3.2 Root Cause Categorization

A root cause-based breakdown of unplanned events is currently used internally to understand trends and support improvement efforts. Based on workshop material and internal analysis, the following categories were identified as the most relevant.

Table 6. Step 2 of the method

Root Cause	Example
Operational issues	Crew misuse and maintenance not performed as agreed.
Product nonconformities	Manufacturing or design defects.
Obsolescence	Components are outdated or no longer supported.
Fluid-related issues	Poor lubrication, fuel, or cooling water management.

Table 6 illustrates a root cause analysis of unplanned maintenance. The decomposition helps to uncover systemic issues that go beyond the immediate cause. For instance, a component failure in an engine might not be a purely technical issue but it might also be caused by poor operating procedures or poor fluid management by the customer.

5.3.3 Scope Definition Based on Agreement Type

During the thesis it became clear that the contract scope has a direct influence on both how unplanned maintenance is reported and who bears the cost. Internally, Wärtsilä differentiates between capped and uncapped scopes, as shown below.

Table 7. Step 3 of the method

Agreement Type	Explanation
Capped Agreement	The agreement includes a fixed budget for unplanned maintenance.
Uncapped Agreement	Wärtsilä covers all unplanned maintenance regardless of volume or cost.

Table 7 presents the two broad categories of agreement scopes utilized in Wärtsilä's Performance Services: capped and uncapped. In a capped contract, the buyer has a budget for unexpected maintenance. When this is exhausted, the money is no longer refundable. In an uncapped contract, Wärtsilä bears the full cost of unexpected maintenance, regardless of how often or how much. This is important to be aware of when tracking the unplanned maintenance.

5.3.4 Digital Logging Systems

A recurring theme in the internal material was the lack of standardized data collection for unplanned events. This makes analysis difficult and limits Wärtsilä's ability to improve proactively. However, ongoing development points to a structured digital logging system as the most effective solution. The table below presents the systems that need to be used to succeed in collecting unplanned data.

Table 8. Step 4 of the method

System	Purpose
Wärtsilä Online	Customers submit unplanned maintenance requests.
Salesforce	Internal processing and categorization of events.
SAP	Manages spare part ordering, tracking, and cost attribution.
Power BI	Enables data visualization and trend analysis.

Table 8 outlines the planned structure for a digital, standardized logging process. This will be supported by the integration of Wärtsilä Online, Salesforce, SAP and Power BI. The results demonstrate that cost-based analysis alone is insufficient for comparing unplanned maintenance and that a structured event-based method provides a more consistent and actionable foundation.

6 Discussion

The aim of this thesis was to determine whether the type of agreement has a significant effect on the number of unplanned occurrences, as well as how unplanned maintenance may be compared among vessels operating under various Wärtsilä Lifecycle Agreements (OMA, GAP, and TMA). I assumed this would be a simple comparison from the beginning with collecting some information, examining cost variations and evaluating the results. But the method soon turned out to be more complicated than expected, and it turned out to be one of the work's most useful features.

My work in the Maintenance Planning department at Wärtsilä over the past year has greatly expanded my understanding of the subject. I was able to observe firsthand how data is evaluated and how service events are initiated and managed. I also got to see the differences in scopes by being close to the planners of actual lifecycle agreements. I was able to identify gaps between process design and process execution. Particularly in areas like spare part logging, contract scope handling and root cause attribution. Without this hands-on experience, the method proposed in this thesis would likely have been more abstract and less applicable to Wärtsilä.

The thesis revealed certain noticeable flaws in Wärtsilä's present procedures. Root cause data is either inconsistently documented or absent. Instead of using organized systems, unplanned events are being monitored in emails or Excel sheets. The planner is frequently aware of scope attribution and whether an event is capped or uncapped, but it is not always recorded in a clear manner that allows for comparison. These restrictions are typical of big service companies going through digital transformation and are not specific to Wärtsilä. However, if unplanned maintenance performance is to be continuously measured throughout time, this needs to be addressed. Mobley's emphasis on the difficulty of cost-justifying predictive maintenance was clearly reflected in this thesis, as cost data alone proved unreliable for analyzing unplanned events (Mobley, 2002).

Another reflection is that although the four-step approach described in this thesis is a useful enhancement, it is not a complete system. It should be viewed as a starting point for further advancement and something that can facilitate improved data organization. The framework also makes it possible to make processes better in SAP, Salesforce and Power

BI, where a large portion of the suggested logic might be incorporated into workflows or dashboards.

Personally, this thesis has been more than just an academic assignment. It has been a learning experience that has forced me to reconsider my views on organizational structure, process improvement and technical data. I discovered that what is measurable on paper frequently isn't in real-world operations and that effective solutions frequently entail refining organization. I also understood the importance of defining terms more precisely rather than merely adding additional data. Additionally, I discovered the importance of integrating practical operational knowledge with critical thinking, particularly in a multinational corporation like Wärtsilä.

This discussion illustrates the journey from an unreliable method to an organized event-based framework that more accurately captures the complexity of unscheduled maintenance. Although the findings are unique to Wärtsilä, they are probably applicable to other service contexts dealing with comparable issues. Above all, the thesis demonstrated that the way we define, record and categorize technical activity has a significant impact on performance evaluation.

7 Conclusion

The purpose of this thesis was to investigate how unplanned maintenance can be compared in a reliable and consistent way across vessels operating under different Wärtsilä Lifecycle Agreements. Finding a technique that accurately captures technical performance and operational realities without being impacted by contract-specific factors, pricing models or consumer discounts was the aim.

At the beginning of the project, I approached the research questions by attempting to make comparisons between various agreement types. I collected and compared cost data using SAP and Service Configurator on a sample of vessels. My initial attempt was to establish the difference between planned spare part usage and actual usage and use this as an indicator of the amount of unplanned maintenance. The approach soon revealed major issues. Customer-specific prices, varying discount levels and contract scope changes during the journey made the data non-comparable. What I had initially thought would be an objective financial measure turned out to be incomparable among 60 vessels.

I shifted focus away from cost and more towards the technical and behavioral aspects. I began to review the internal reports within Wärtsilä on unplanned maintenance, including strategic slides, risk management reports, field service reports and categorization of the spare parts. I found that unplanned maintenance is already addressed within the company in a way, but it is not yet completely standardized in tracking and comparing. This was a key turning point in the thesis because instead of building the model from scratch, I started overlaying the comparison methodology on current Wärtsilä practice.

My next step was to map out the categories used internally to classify unplanned maintenance events. Condition-based replacement, unscheduled overhaul part replacement, and unexpected failures due to operation or problem of quality fall under this. I analyzed the application of these definitions for planning purposes with the Service Configurator and their alignment with the actual work on vessels.

To elevate the analysis further, I then looked at the treatment of root causes. Presentations from technical risk management and performance services provided detailed insight into the most common drivers of unplanned work: product nonconformities, crew handling errors, obsolescence and a poor fluid management. I learned that any effective comparison

of unplanned maintenance must go beyond just the what and proceed with why this was happening. That turned out to be the second level of the proposed comparison framework.

Another key insight came from looking at contract scope attribution. It became evident that whether an agreement is capped or uncapped has a big impact on how difficulties are reported as well as how costs are absorbed. While the customer may become more cost conscious or selective in their reporting in capped circumstances, Wärtsilä is responsible for the full cost of unforeseen expenses in uncapped agreements. I concluded that any comparison framework must take this into account since it has a direct impact on the transparency and traceability of unplanned maintenance data.

I also looked at Wärtsilä's digital tools and reporting structures. The absence of a completely defined procedure for recording unscheduled maintenance events at Wärtsilä is one of the thesis's main conclusions. Excel spreadsheets, email conversations and team specific interpretations are major components of current procedures. This type of way is not good enough when you are dealing with hundreds of vessels. Nonetheless, internal projects demonstrate that a move toward structured digital logging is already under way, such as the planned integration of Wärtsilä Online, Salesforce, SAP and Power BI. This change is enhanced by my suggested approach, which offers a framework that could be used with those systems.

To compare unplanned maintenance in an efficient way, a four-step approach was created:

1. Classify event kinds
2. Monitor root causes
3. Define agreement scope attributions
4. Guarantee digital logging and structure

This model is designed to be both theoretically and practically applicable, and it is based on Wärtsilä's internal reasoning and continuous improvement. Although comparing unexpected maintenance using cost data was the original objective, this thesis produced something more useful. An approach that is scalable and structured that considers Wärtsilä's own definitions, risks and goals. Better benchmarking is made possible by this approach, and it also facilitates proactive problem solving while fitting the business's

strategic goals of performance transparency and digitization. The study also identifies areas that require improvement, particularly in data standards and system integration.

7.1 Further Research

One natural next step would be to apply the framework to a broader sample of vessels and Lifecycle Agreement types to test its scalability and adaptability under varying contract conditions. As Wärtsilä continues to develop its internal systems, there is significant potential to incorporate predictive analytics based on condition monitoring data. This would allow for a more proactive and accurate approach to tracking unplanned maintenance, moving beyond historical analysis toward real-time decision support.

In addition, future theses or internal projects could focus on refining the root cause classification model introduced in this work by developing clearer definitions and digital templates for structured event logging. Further research could also assess the effectiveness of integrating this comparison framework into operational systems such as Salesforce. Doing so would enable automatic reporting and benchmarking of unplanned events across fleets and agreements.

Ultimately, this thesis should be seen as a foundation for further development. The findings and methods presented here aim to contribute to Wärtsilä's ongoing efforts to improve lifecycle agreement performance, customer satisfaction and long-term asset reliability.

8 Bibliography

- Abdul, R., Chamarchy, S. S., Balasubramaniam, V. S., Prasad, M., Kumar5, S., & Sangeet. (2020). Advanced Applications of PLM Solutions in Data Center Infrastructure Planning and Delivery. *International Journal of Applied Mathematics, Volume 9 (4)*, 125-154. Retrieved 03 13, 2025, from https://www.researchgate.net/profile/Rafa-Abdul/publication/388827034_Advanced_Applications_of_PLM_Solutions_in_Data_Center_Infrastructure_Planning_and_Delivery/links/67a841f88311ce680c5a177a/Advanced-Applications-of-PLM-Solutions-in-Data-Center-Infrastru
- B. Jones, R. (2011). *Risk-based management : a reliability-centered approach*. Taylor & Francis Group. Retrieved 03 12, 2025, from <https://ebookcentral-proquest-com.ezproxy.novia.fi/lib/novia-ebooks/detail.action?docID=1649062>
- Blenkey, N. (2016). New Wartsila agreements give performance guarantee. *Marinelog*. Retrieved 02 26, 2025, from <https://www.marinelog.com/news/wartsila-lifetime-solutions-agreements-now-have-performance-guarantee>
- Bryman, A. (2012). *Social Research Methods*. Oxford University Press. Hämtat den 28 02 2025
- K.Shridhara, B. (2008). *Materials Management* (Vol. 4). Himalaya Publishing House Pvt. Ltd. Retrieved 02 23, 2025, from <https://ebookcentral-proquest-com.ezproxy.novia.fi/lib/novia-ebooks/reader.action?docID=3011314&ppg=1>
- Karatuğa, Ç., Arslanoğlu, Y., & Soares, C. (2023). Review of maintenance strategies for ship machinery systems. *Journal of Marine Engineering & Technology, Volume 22 (5)*. Retrieved 03 11, 2025, from <https://www.tandfonline.com/doi/full/10.1080/20464177.2023.2180831>
- Krebsbach, H. (2025). *What is PLM (Product Lifecycle Management)?* Retrieved 02 13, 2025, from Atlassian: <https://www.atlassian.com/agile/product-management/plm>
- Lambert-Torres, G., Leandro Bonaldi, E., & Eli de Lacerda de Oliveira, L. (2020). *Maintenance Management - Current Challenges, New Developments, and Future Directions*. IntechOpen. Retrieved 02 03, 2025, from https://mts.intechopen.com/storage/books/11528/authors_book/authors_book.pdf
- M. Smith, A., & R. Hinchcliffe, G. (2003). *RCM--Gateway to World Class Maintenance*. Elsevier Science & Technology. Retrieved 03 11, 2025, from https://triton.finn.fi/novia/Record/abo_electronic_novia.9913461364505972?sid=4959125939
- Mobley, R. (2002). *An Introduction to Predictive Maintenance* (Vol. 2). Elsevier Science & Technology. Retrieved 03 24, 2025, from <https://ebookcentral.proquest.com/lib/novia-ebooks/reader.action?docID=293982&ppg=5>
- Mouschoutzi, M., & T.Ponis, S. (2022). A comprehensive literature review on spare parts logistics management. *The Asian Journal of Shipping and Logistics*, 71-83. Retrieved 02 27, 2025, from

https://www.researchgate.net/profile/Maria_Mouschoutzi/publication/357663422_A_comprehensive_literature_review_on_spare_parts_logistics_management_in_the_maritime_industry/links/64133b20a1b72772e4020b1b/A-comprehensive-literature-review-on-spare-parts-log

- Poljak, I. (2022). Marine Power Systems. *Journal of Marine Science and Engineering*, 10, 195. Retrieved 02 12, 2025, from https://mdpi-res.com/bookfiles/book/5027/Marine_Power_Systems.pdf?v=1738548249
- Somani, A. (2021). Management And Procurement Of Spares On Ships – How To Identify, Order And Reduce Costs. *Marine Insight*. Retrieved 02 26, 2025, from <https://www.marineinsight.com/life-at-sea/management-and-procurement-of-spares-on-ships-how-to-identify-order-and-reduce-costs>
- Tripathi, A., & Prasad , M. (2024). RCM based optimization of maintenance strategies for marine diesel engine using genetic algorithmsv. *International Journal of System Assurance Engineering and Management*, Volume 15, 3757-3775. Retrieved from https://triton.finn.fi/novia/PrimoRecord/pci.cdi_crossref_primary_10_1007_s13198_024_02374_z?sid=4959015563
- Udroiu, R., & Bere, P. (2019). *Product Lifecycle Management - Terminology and Applications*. IntechOpen. Retrieved 03 20, 2025, from https://mts.intechopen.com/storage/books/7489/authors_book/authors_book.pdf
- Wärtsilä. (2024). *Careers*. Retrieved 12 18, 2024, from <https://www.wartsila.com/careers>
- Wärtsilä. (2024). *Hybrid ships: a surprising reason they are such an excellent idea*. Retrieved 02 24, 2025, from Wärtsilä: <https://www.wartsila.com/insights/article/hybrid-ships-a-surprising-reason-they-are-such-an-excellent-idea>
- Wärtsilä. (2024). *Our businesses*. Retrieved 12 18, 2024, from <https://www.wartsila.com/about/this-is-wartsila>
- Wärtsilä. (2024). *Performance Services*. Retrieved 12 18, 2024, from <https://wartsila.sharepoint.com/sites/INT-Marine-Power-Performance-Services>
- Wärtsilä. (2024). *The History of Wärtsilä*. Retrieved 12 18, 2024, from <https://www.wartsila.com/about/history>
- Wärtsilä. (2024). *Why less critical spare parts for ships may matter more than you think*. Retrieved 03 10, 2025, from Wärtsilä: <https://www.wartsila.com/insights/article/why-less-critical-spare-parts-for-ships-may-matter-more-than-you-think>
- Wärtsilä. (2025). *4-Stroke Engine Services*. Retrieved 02 26, 2025, from Wärtsilä: <https://www.wartsila.com/marine/services/4-stroke-engine-services>
- Wärtsilä. (2025). *Financial Statements Bulletin January–December 2024*. Retrieved 03 19, 2025, from Wärtsilä: <https://www.wartsila.com/docs/default->

source/investors/financial-materials/interim-reports/financial-statements-bulletin-2024.pdf?sfvrsn=d7694f42_1

Wärtsilä. (2025). *Marine services*. Retrieved 02 26, 2025, from Wärtsilä:
<https://www.wartsila.com/marine/services>

Wärtsilä. (2025). *Shaping the decarbonisation of marine and energy Roadshow presentation*. Retrieved 02 26, 2025, from
https://www.wartsila.com/docs/default-source/investors/financial-materials/other-ir-presentations/roadshow-presentation-february.pdf?sfvrsn=d53d5042_3

Wärtsilä. (2025). *Ship spares: Five top tips to help keep your operations compliant*. Retrieved 03 10, 2025, from Wärtsilä:
<https://www.wartsila.com/insights/article/ship-spare-five-top-tips-to-help-keep-your-operations-compliant>

Zhang, Y., Ren, S., Sakao, T., & Huisinigh, D. (2017). A framework for Big Data driven product lifecycle management. *Journal of Cleaner Production*(159), 229-240. Retrieved 02 28, 2025, from Journal of Cleaner Production:
<https://www.sciencedirect.com/science/article/pii/S0959652617309150>

Appendix 1. Interview Questions Interview 1 – Senior Technical Quality Manager

1. What is your knowledge or experience with unplanned maintenance?
2. Based on your experience, what are the most common causes of unplanned maintenance in vessels managed by Wärtsilä?
3. Do you think the term “unplanned maintenance” is clearly defined and used consistently within Wärtsilä?
4. What are the biggest challenges in tracking and comparing unplanned maintenance today?
5. How do different agreement types (OMA, GAP, TMA) affect the handling or occurrence of unplanned maintenance?
6. What improvements would you like to see in how Wärtsilä logs, classifies and analyzes unplanned maintenance?
7. How do you see the potential for improving traceability through digital tools such as SAP and Salesforce?
8. Is there anything important to understand about unplanned maintenance that may not always be visible in the data?