National Technical University of Athens
School of Naval Architecture & Marine Engineering
Laboratory for Maritime Transport

Quality Management Systems: A Lean Approach

Diploma Thesis
of

Nikolaos Mitropapas
08113061

Supervising Professor
Nikolaos P. Ventikos

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Abstract

Shipping is playing a significant role in the global trade and economy, by transporting 80% of the total cargoes' volume. At the same time, it is observed that the maritime industry is subject to multiple regulatory frameworks, such as MARPOL, SOLAS, UNCLOS, MLC, Flag Registers', IMO's and Classification Societies' requirements, usually creating a serious administrative burden, both for the crew and the personnel ashore. Even though management is prompting its fleet to adopt new techniques and improvements, it is common that these changes are not effectively performed by the crew, due to increased documentation and bureaucratic processes. In addition to their actual responsibilities, deck and engine officers are also expected to complete and submit numerous forms, as per ISM Code, to assure that the office personnel are informed about the vessels' status and crew's safety (machinery operational data, noon reports, inventories status etc.).

The goal of the present diploma thesis is to investigate the application of the Lean Management in the Safety Management System (SMS) of a well-established shipping company, Tsakos Columbia Shipmanagement "TCM" S.A., in order to address the bureaucratic processes and the crew's fatigue, as a consequence. In particular, the methodology, 'Lean Transformation' is developed, inspired by the Toyota Production System, which embraces the mentality of lean and process's continuous improvement ('kaizen'). It enables a company to evaluate the performance of existing processes, by mapping its scope and value, redesigning and optimizing its implementation, while incorporating new technologies and best practices. The methodology can be employed to transform all of the company's SMS, but for the scope of the thesis, is applied on the Main Engine Performance reporting process. During the implementation phase, the data collected by integrating signals from various sensors onboard (Alarm & Monitoring and Engine Diagnostics Systems) of a Suezmax Shuttle Tanker, as well as from the fuel oil analysis (FOBAS). The signals and data were incorporated into the company's ERP, to provide an automated reporting system, without the human element involved. Following the implementation, a study has occurred, to evaluate the efficiency rate and the personnel's satisfaction level, with respect to the redesigned process. The results of this study showed that the selected process can be automated up to 87%, while the overall satisfaction level was identified at 7.5/10, with 100% of the participants agreeing that digital transformation of the ISM Code is an effective method to reduce crew's workload.

In Chapter 1, after a brief historical recursion, an introduction to the industry's main challenges and management practices. Following, in Chapter 2, the academic foundations of the study are being set, investigating the applications in literature. While in Chapter 3, Lean Transformation methodology is developed and thoroughly explained. Chapter 4 illustrates the methodology implementation on the ME Performance reporting process. Next, in Chapter 5, an evaluation of the study's findings and the results of the survey are presented. Finally, Chapter 6, is a conclusion with summary of the results and identification the study's weaknesses and future extensions.

Περίληψη

Η ναυτιλία διαδραματίζει σημαντικό ρόλο στο παγκόσμιο εμπόριο και οικονομία μεταφέροντας το 80% του συνολικού όγκου των φορτίων. Ταυτόχρονα, παρατηρείται ότι η ναυτιλιακή βιομηχανία υπόκειται σε πολλαπλά ρυθμιστικά πλαίσια, όπως οι απαιτήσεις της MARPOL, SOLAS, UNCLOS, MLC, των Νηολογίων, των Νηογνωμόνων και του IMO. Συχνά, το ρυθμιστικό πλαίσιο που αναπτύσσουν οι εν λόγω οργανώσεις, μεταφράζεται σε γραφειοκρατία, τόσο για το πλήρωμα όσο και για το προσωπικό στην ξηρά. Παρόλο που η διοίκηση προτρέπει τον στόλο της να υιοθετήσει νέες τεχνικές και βελτιώσεις, είναι σύνηθες, αυτές οι αλλαγές να μην εκτελούνται αποτελεσματικά από το πλήρωμα, λόγω της αυξημένης τεκμηρίωσης και των γραφειοκρατικών διαδικασιών. Εκτός από τις πραγματικές αρμοδιότητές τους, οι αξιωματικοί του καταστρώματος και της μηχανής καλούνται να συμπληρώσουν και να υποβάλουν πολυάριθμες φόρμες, σύμφωνα με τον Κώδικα ISM, για να βεβαιωθούν ότι το προσωπικό του γραφείου ενημερώνεται για την κατάσταση του πλοίου και την ασφάλεια του πληρώματος.

Στόχος της παρούσας διπλωματικής είναι η διερεύνηση της χρήσης της Λιτής Διαχείρισης (Lean Management) στο Σύστημα Διαχείρισης Ασφάλειας (SMS) μιας μεγάλης ναυτιλιακής εταιρείας, της Tsakos Columbia Shipmanagement "TCM" S.A., προκειμένου να αντιμετωπιστούν οι γραφειοκρατικές διαδικασίες και η κόπωση του πληρώματος. Συγκεκριμένα, αναπτύσσεται μια μεθοδολογία, η Lean Transformation, εμπνευσμένη από το σύστημα παραγωγής της Toyota, η οποία αγκαλιάζει τη νοοτροπία της συνεχούς βελτίωσης των διαδικασιών («kaizen»). Επιτρέπει σε μια εταιρεία να αξιολογεί την απόδοση των διαδικασιών της, χαρτογραφώντας την χρησιμότητα και την προστιθέμενη αξία τους, επανασχεδιάζοντας και βελτιστοποιώντας την υλοποίησή τους, ενσωματώνοντας ταυτόχρονα νέες τεχνολογίες και πρακτικές. Η μεθοδολογία μπορεί να χρησιμοποιηθεί για τη μετατροπή ολόκληρου του SMS της εταιρείας, όμως στην συγκεκριμένη εργασία, εφαρμόζεται στην διαδικασία αναφοράς της απόδοσης της κύριας μηχανής. Κατά τη διάρκεια της υλοποίησης, τα δεδομένα συλλέχθηκαν συνδέοντας σήματα από αισθητήρες του πλοίου (Alarm & Monitoring and Engine Diagnostics Systems) καθώς και από την ανάλυση καυσίμου (FOBAS), ενός Suezmax Shuttle Tanker. Ύστερα, τα δεδομένα ενσωματώθηκαν στο ERP της εταιρείας, παρέχοντας ένα αυτοματοποιημένο σύστημα αναφοράς. Μετά την εφαρμογή, πραγματοποιήθηκε μια μελέτη για την αποτελεσματικότητα και την ικανοποίηση του προσωπικού σε σχέση με την επανασχεδιασμένη διαδικασία. Τα αποτελέσματα, έδειξαν ότι η νέα διαδικασία μπορεί να αυτοματοποιηθεί έως και 87%, ενώ το συνολικό επίπεδο ικανοποίησης προσδιορίστηκε στο 7.5/10, με το 100% των συμμετεχόντων να συμφωνούν ότι ο ψηφιακός μετασχηματισμός του Κώδικα ISM είναι μια αποτελεσματική μέθοδος για τη μείωση του φόρτου εργασίας του πληρώματος.

Στο Κεφάλαιο 1, μετά από μια σύντομη ιστορική αναδρομή, γίνεται μια εισαγωγή στις κύριες προκλήσεις και πρακτικές διαχείρισης του κλάδου, ενώ στο Κεφάλαιο 2 τίθενται τα ακαδημαϊκά θεμέλια της μελέτης, εξετάζοντας την υπάρχουσα βιβλιογραφία. Στο Κεφάλαιο 3 αναπτύσσεται και επεξηγείται η μεθοδολογία Lean Transformation, ακολουθούμενη από την εφαρμογή της μεθοδολογίας στην διαδικασία αναφοράς της απόδοσης της κύριας μηχανής, στο Κεφάλαιο 4. Στη συνέχεια, στο Κεφάλαιο 5 παρουσιάζεται η αξιολόγηση των ευρημάτων της μελέτης και τα αποτελέσματα του ερωτηματολογίου. Τέλος, στο Κεφάλαιο 6, αναπτύσσονται τα συμπεράσματα, προσδιορίζονται οι αδυναμίες της μελέτης και οι μελλοντικές της επεκτάσεις.

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In addition, I would like to acknowledge my father who, after years of experience with Quality Management Systems, stood beside me, supporting me to develop the study's methodology, providing me with crucial insights of how management systems behave within a company and how same react in changes.

Finally, I would like to express my deepest gratitude to my colleagues from Energy and Environmental department, at Tsakos Columbia Shipmanagement "TCM" S.A., for their suggestions and continuous assistance, along with my friend and manager Mr. Dimitrios Kyritsis, who 'implanted' the concept of the industry's digital transformation in my mind and guided me carefully to present innovative ideas to the academic environment.

Contents

Figures

Tables

1 Introduction

1.1 Shipping Industry Through the Time

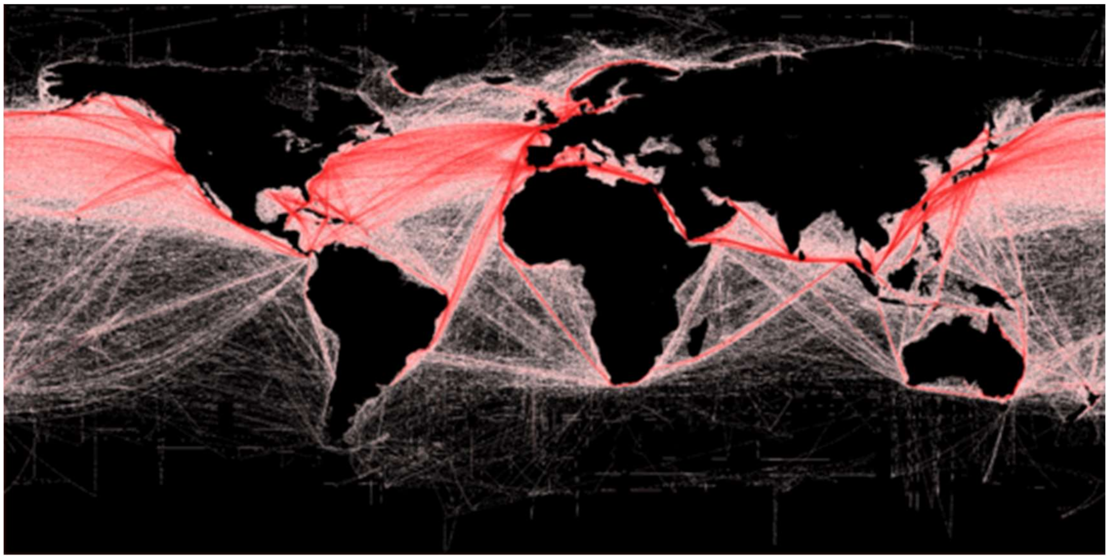


Figure 1. Density of commercial shipping around the globe / Source: Halpern et al., 2008

Shipping has always been the primary method of goods transportation all around the globe, while is proved to be a major factor of human evolution since the ancient times. Exploration, trading, goods transportation, entertaining traveling and fishing are only a few of the uses of ships though the years. The majority of people on earth have a strong connection with the sea and the density of sea routes is a strong evidence (see Figure 1. Density of commercial shipping around the globe).

It is a fact that over 80% by volume and 70% by value of the global trade are carried by the sea[1], as it is the most cost-effective way for transportation of bulk and large quantities, minimizing the risks and the human exposure involved. At the same time the 15% of the protein consumed every day originates from the seafood.

For humanity, exploration, control and exploitation of sea routes have always been the main source for development of trade and economy, facilitation of communication, transportation and the spreading of culture. Even since the 10000 BC, civilizations from the north coast of Africa, demonstrated technical knowledge and skills required to sail the Mediterranean Sea and be able to colonize the neighboring countries. Archeological findings also indicated strong connection with the sea in Cyclades, Crete and Cyprus as early as 7000-6000 BC.

The development of the industry has started long before the introduction of the internal combustion engines, which elevated the performance to a whole different level, as existing findings also indicate wooden ships constructed in Egypt as early as 2613 BC (Name: Praise of the

[1] https://unctad.org/en/PublicationsLibrary/rmt2018_en.pdf

Two Lands)[2]. The main areas in which shipping growth was observed were Egypt and Mesopotamia, already in the fourth millennium BC, with strong trade and transport. The reason was mainly the great difficulties in land transport (times prior to the invention of the wheel) and mainly related to river routes. The people of Aegean islands were the first to proceed with proper shipbuilding, with the first ships with wooden keel, aiming to a more robust construction, able to withstand heavier weather and longer trips. During the first centuries of the second millennium BC, Crete appeared as an important naval force in the forefront. Most ships at that time were sailing with one to three masts, while the propulsion was also made with paddles. Later came the Mycenaeans, developing a very strong naval force, while their skills in navigation and shipbuilding reached them to Euphonic Pontus, the eastern Mediterranean, Italy and even more to the west.

At the same time strong naval activity was observed by Phoeniches, because of their lack of natural resources, they had to turn to the sea trade, with Egypt and Syria. Significant ports along the coasts of Africa and the southern coasts of Spain developed, thus, shipping began to evolve at a rapid pace, merchant vessels strolled from the Mediterranean to eastern Europe and Britannic islands. For the first time in history, ships began from Red Sea and sailed all around Africa to Gibraltar (600 BC). Greek merchant shipping becomes a great power of that time, sailors explore the coast of Adriatic and colonize Southern Italy, from where they headed to western Mediterranean and further to the Atlantic Ocean. Others departing for Indian Ocean, Arabia and East Africa. At that time, shipping is a common mean of transportation and trade, big ports have been formed and ships reach every continent, the astrolabe is invented, while Archimedes presents very important work on the basic principles of hydrostatic and the stability of floating bodies.

The majority of ships during the ancient times were intended for military purposes, for that reason exactly the innovation happened fast, due to competition. Mathematics began to be more sophisticated; nature is being decoded more and more, logistics and accounting began to appear, thus the naval architecture is developing. Later, due to the economy's collapse, by Romans, large scale shipping and trading stops, along with the innovation and evolution of the markets. Slowly, the control of the Mediterranean will pass to the Byzantines and the Arabs and later to the Italian cities of Genoa and Venice. Then, during the 12th century, Hanseatic League was created, a commercial and defensive confederation of merchant guilds and market towns in Northwestern and Central Europe. Growing from a few North German towns in the late 1100s, the league came to dominate Baltic maritime trade for three centuries along the coasts of Northern Europe.

Despite all the progress gained on Western Europe, recovering from the dark times of Middle Ages, the real growth and innovation in shipbuilding and navigation takes place in the Far East, where China for centuries dominates the worlds seas (1300-1400). The recent rise of the Ming's dynasty leads the country into an extroverted policy with a specific boost to trade in South-Eastern Asia. Chinese shipbuilders are already familiar with the use of transverse watertight

[2] Anzovin, Steven et al., *Famous First Facts*

hedges to limit water flooding in the case of a crack in the vessel's hull, while the compass is an inseparable tool of the ship's navigation.

With time, western Europe, evolved into a new stage, with serious social, political and economic developments, having a huge impact in technical knowledge also. Spices from the east attracted famous seafarers to head to India and Arabic peninsula. Portuguese became the greatest pioneers and explorers of the history, while trying to find alternative routes to the east, they sailed all around South Africa and the Cape of Good Hope (Bartolomeu Dias, 1488[3]). Spanish seafarers, led by the ambitious Christopher Columbus, in their effort to reach for China, they crossed the Atlantic Ocean within 69 days and discover America, changing once and for good the course of history (1492[4]). Later, a Spanish expedition organized by the Portuguese explorer Magellan, resulted in the first circumnavigation of the Earth (1519-1522). That was the time when the last frontier was surpassed, since then, maritime trade evolved rapidly. Soon, industrial revolution and the introduction of the mechanical propulsion changed the way ships are perceived.

Steam propulsion was integrated in ships quickly, and the relevant technology began to develop in both sides of the Atlantic Ocean, resulting in the first cross of it, with Savannah, a sailing vessel which used a steam auxiliary engine (1819). Later, two British ships crossed it again without the use of sails for the first time (1838). Another big leap in the technology of shipbuilding was made on 1821, when the first vessel made of steel was built.

Since then, technology's development, accompanied by the rapid expansion of the markets, lead to high performance vessels, able to cross oceans within days, with increased strength and durability against nature's elements.

1.2 Modern Shipping

Times are changing, as the development and the innovation of technology are in an accelerating rate. The earth's population is increasing by thousands daily, thus the energy demands are getting higher, the petroleum products are needed more and more, the fishing industry is expanding rapidly and the timeframe for all these transports is getting smaller. One could say that the shipping industry is on a development rally over the last century, along with a great industrial revolution which takes place daily. But how does the industry react about all that progress?

Companies within the industry are facing real and high complexity challenges, which are difficult to be defined by an outsider. All this development, transportation and energy consumption comes with a price, which is not always monetary. The market is expanding, so does the risk involved in it. Safety has been compromised more than a few times over the last century, and

[3] https://www.history.com/topics/exploration/bartolomeu-dias
[4] https://www.history.com/this-day-in-history/columbus-reaches-the-new-world

even if the measures taken are a lot and the progress is daily, the human element proves to be exposed more than it should.

The crew onboard tends to be minimal, while the performance of the machineries must be optimal. Everything is aiming towards optimization and efficiency increase. It is of high importance though, the development to be equal in all market's aspects, both in performance and in management systems, in order to ensure that no discounts will be made. Such discounts may affect either crew's safety, or environment's protection or property's insurance or adequate management practices.

The standards have to be set high, for a company to assure full compliance with existing and upcoming rules, regulations, new laws and other applicable restrictions. The structure's complexity is so high that regulating bodies and other related parties are coming from all directions. Other bodies aim for safe work environment, energy efficiency, environmental protection, optimized operations, risk minimization investments' advisory or other reasons. The most important condition, for a competitive company, in order to be able to achieve its goals, while at the same time be on an expansive course, is to be well aware of its affiliates as well as its environment.

A brief presentation of some of these affiliates, will demonstrate a wider picture of the challenges of the market due to its complicatedness, along with the contribution of shipping industry in multiple levels of the society. Each of the below parties, represents a different perspective of the industry, with very contradicting interests and contrasting affections. All of them, though, support a multibillion industry, providing energy, food, technology and other necessities worldwide.

The main regulating body of the shipping industry is International Maritime Organization (IMO), which is responsible to develop and constantly maintain a comprehensive regulatory framework. Its agenda includes safety, environmental concerns, legal matters, technical cooperation, maritime security and the efficiency of shipping. For each of the above components, a different convention or committee is responsible to provide the guidelines and the standards operating procedures, for the compliance of the vessels and their respective companies.

The first and most important convention is SOLAS 74 (Safety of Life at Sea), which was first introduced in 1914. It mainly addresses the safety of the merchant ships and the human element involved. It is an international maritime treaty, which sets minimum safety standards in the construction, equipment and operation of the ships, and it is the starting point of most of the vessels' structural regulations. Each vessel's Flag State is responsible to ensure its compliance with the applicable standards and the prescribed certificates. The current version of SOLAS Conventions consists of 14 chapters, inclusive of Construction Instructions, Radiocommunications, Safety of Navigation, Management of the Safe Operations of Ships, Measures to enhance Maritime Security, Verification of Compliance etc.

Next significant convention is MARPOL 73/78 (Maritime Pollution), the international convention for the prevention of pollution from ships. It is an effort to minimize pollution of the oceans and seas (oil and air pollution). This convention addresses matters regarding the accidental oil, or other toxic substances or spillage. It is considered as a convention with very active enforcement worldwide, as it includes specific regulations for the control of pollution by noxious liquid substances in bulk, the prevention of pollution by harmful substances in packaged form, by sewage and garbage from ships and the air pollution from engines and other machineries. It consists of 6 Technical Annexes, which give specific details and guidance on various operational matter that may affect the environment, while at the same time strict controls on vessel's discharges are applied.

Another important IMO's convention is the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), 1978, which sets the minimum qualification standards for masters (vessels' Captains), officers and watch personnel on seagoing merchant ships. In previous years, standards were set by individual governments, which led to a wide variety of requirements, causing great difficulties to an international industry such as shipping. Today, each country is obligated to meet or exceed these standards. STCW code is divided in two main parts, A and B. Part A is mandatory while Part B included recommendations on the implementation of the convention. It consists of 8 chapters, including Engine Department Personnel, Master and Deck department, Radio communications and radio personnel etc.

In the meanwhile, countries, thus; vessels and companies too, must also comply at all times to the United Nations Convention on the Law of the Sea (UNCLOS), which is an international agreement to define the rights and responsibilities of nations with respect to their use of world's oceans, establishing guidelines for businesses, the environment, and the management of marine natural resources. At the same time, another convention MLC (Maritime Labor Convention), embodies all up-to-date standards of existing international maritime labor conventions and recommendations. It is considered as a guide for the minimum working and living standards for all seafarers working on ships flying the flags of the validated countries.

The above conventions are considered as Key Conventions, but they are only a few amongst hundreds of international mandatory requirements. Others may cover Liabilities and Compensations or Tonnage Measurement and Salvage. The majority of them, prescribe a minimum compliance level for all vessels and shipping companies in order to be legally operational. Within such strictly structured market, a body to guide companies through regulations and legal requirements is of high importance. Classification Societies are the steppingstones for every shipping company to achieve adequate regulatory policies and safe work environments.

Classification Societies are organizations that establish and maintain technical standards for the construction and operation of the ship, certifying that the construction complies with the international standards, after carrying out regular surveys to ensure continuing compliance.

Several well-known and respectable societies have formed a body, called IACS (International Association of Classification Societies), which is the main regulating body regarding the structural and other requirements (because it sets the limits higher than the IMO's conventions). In order to have a classification society though, same must be recognized by the ship's registry.

International law requires that every merchant ship shall be registered in a country, called its flag state. A ship's registry, the country which gives a ship its nationality, in order to allow it to travel internationally and use it as a proof of ownership, or else said, to acknowledge it as an entity. Vessels are required only to comply with globally agreed upon standards subject to enforcement by the flag state, which is responsible to "ensure compliance with international rules and standards" and to provide the relevant "effective enforcement" no matter where violations occur. A vessel may be flying a specific flag, collaborating with another country's classification society, to ensure its compliance with the relevant standards, in order to be able to trade worldwide.

On top of all the above, comes the International Safety Management Code (ISM) by IMO, whose purpose is to provide an international standard for the safe management-operation of the ships and for pollution prevention. In other words, ISM embodies the majority of the conventions, rules and regulations, international laws and requirements in order to provide a proof that a ship-management company and in extension, a vessel, complies with the global standards and is able to operate smoothly.

Finally, there are also National and Regional Requirements, which are compulsory for a vessel, operator or management company to comply in order to be able to trade within specified areas. One major regional requirement for example is the EU MRV (Monitoring, Reporting, Verification) regulation, which was entered into force on July 1st, 2015 and requires ship owners and operators to annually monitor, report and verify CO_2 emissions for vessels calling any EU port. EU requires total control of the major polluting sources of a ship trading within its limits. Along with the example, hundreds of other countries or unions of countries, have their own requirements, which most of the times are much stricter than the respective IMO's regulations.

It is apparent from the above, that the environment in which a shipping company is required to develop is constantly expanding and the interrelations of all these components are of high complexity (see Figure 2. A vessel's major affiliates). Minimum standards compliance is not enough for an organization to survive, let alone to expand and be profitable, as guidelines set by the law, demonstrate the least optimized method to exist as a business entity.

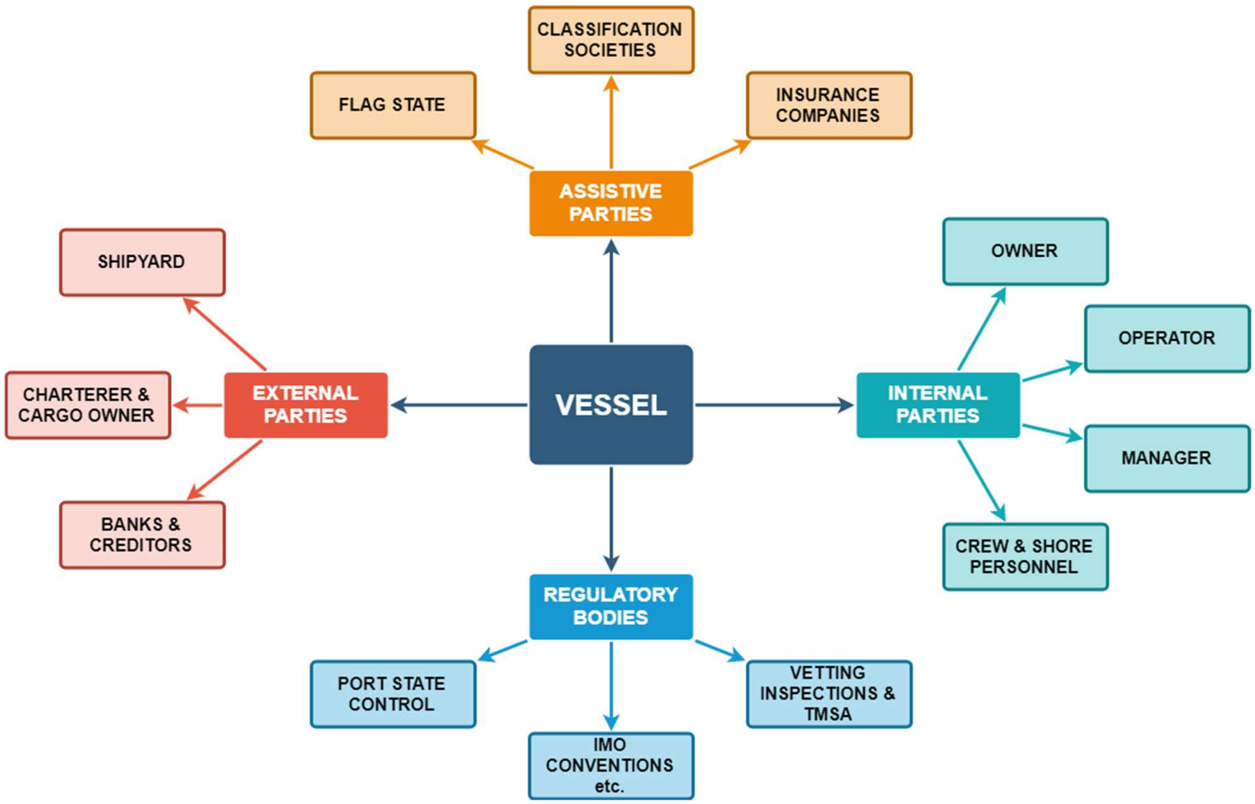


Figure 2. A vessel's major affiliates

1.3 Challenges & Management

Being competitive requires standards to be set high, sustainability to be embedded into company's procedures and processes optimization to be an element of the culture. Strong quality management processes consist an integral part of a competitive organization, able to attract respectable clients, meet their needs and develop a network of trustworthy associates, connections and acquaintances, while at the same time to be able to handle risks and challenges with ease.

Apart from the compliance with the regulations and the satisfaction of the commercial clients, a company must be able to meet its employees, owners, shareholders and other related parties' expectations. Each organization, builds its own culture and acquaintances, the majority of them, have the same goal, though, to be able to withstand dire and challenging times of the market, adjust their strategy to achieve higher standards and ultimately, to be at a competitive level, expanding their services and profits.

The existence of a shipping company begins with its foundation. At that time, its first priority is to be compliant with the minimum legal requirements, such as IMO standards, SOLAS convention etc. As a result, its main investments and efforts shall be heading that way, which will allow it to attract clients. That level can be defined as Level 0 or as per Figure 3. Levels of a Company's Development, as the stage "EXIST". Having achieved that level, an organization is in a position to decide its status in the market, taking always under consideration the risks that it is willing to undertake along with the margins of profit. The next stage of development is to be able to satisfy its customers' needs and requirements, with the use of an adequate safety management system, on-time cargo delivery, safe operations and management of risks involved. That stage segregates the quality level of different companies, the desired clients and their respective reliability.

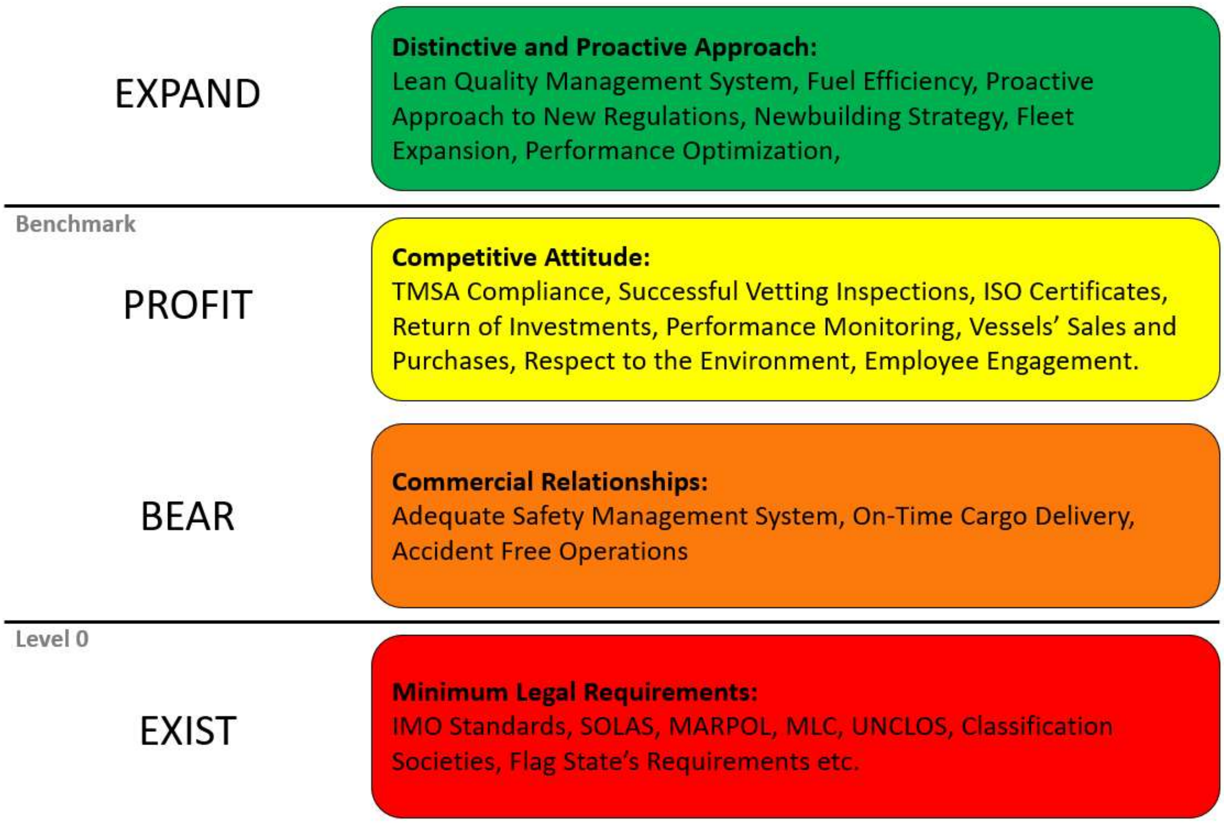


Figure 3. Levels of a Company's Development

Organization that have achieved the second stage of development, "BEAR", will be able to grow further, aiming for high safety and efficiency standards, such as requirements set by Oil Majors known as Tanker Management Self-Assessment (TMSA), or may target to achieve successful vetting inspections, various ISO Certificates (9001, 14000 etc.). At that stage, a company is also able to focus on the respect to the environment, through various environmental campaigns, ensuring that employees understand the impact of their company to the society and the relevant consequences that may create, even if they are above minimum legal requirements. That level of development may be called "PROFIT", as the company has achieved a well-established position in the market, with reputable clients and is profitable.

The ultimate level is "EXPAND", which is the place where only highly competitive companies, with maximum efficiency organizational management, can exist. Effective management along with the obliteration of bureaucracy is a strong characteristic of such organizations, which lead to the accomplishment of profits maximization through performance optimization, fuel efficiency, vessels' new building strategy and most the important of all, proactiveness against the industry's constantly changing environment and upcoming regulations. The competition is high, and it is very common that along with a company's growth, bureaucratic procedures develop. Even though bureaucracy may aim to maintain uniformity and control within the organization, it is strongly associated with the reduction of the corporate efficiency, while it implies additional and hidden costs. Technology is expanding rapidly, reducing human errors and increasing efficiency, the people's previous culture and incorporated mentalities are being stagnated though, which translates to a slow-moving industry, assimilating obsolete management methods.

Shipping industry is not known for its adaptivity to innovation, as it is based on tradition and the maritime spirit of the senior seamen and captains. The market was built on tradition all these years and its expansion was great, but the standards have changed a lot since then. The regulations of shipping imply additional costs to the ship owners, and the change of culture towards adjustability and adaptivity of new management methods is imperative, today more than ever. The main reason why the shipping industry is reluctant to innovative methods and progressive management is that there is a misconception that strict legal framework and regulations equate to increased costs[5]. As a result, the continuous increase of that framework seems like an enemy, while the true enemies are inadequate managerial adaptivity in terms of proactiveness, regulatory readiness and change of culture. By identifying the actual barriers that stand between the regulations and relevant costs, a company may be able to achieve a full conformity with the regulations, without compromising operations by an increasing volume of processes, forms and manuals.

In a more detailed analysis, it can be observed that there is a really strong bond between compliance and sustainability, as shown in the below equation. Explaining, by being compliant, a company achieves risks minimization and less expenses in safety and accidents, while at the same time, by being sustainable, is able to invest in compliance. For that strong connection to exist, a company shall obliterate its bureaucratic procedures, allowing itself to "sail" with ease against incoming regulations and strict requirements, not by voluminous manuals and bureaucratically standardized procedures, but with a **lean approach on management**.

$$Sustainability\ <=>\ Compliance$$

With the regulating bodies pushing from all directions and pollution and safety requirements increasing rapidly, it is the right moment for the industry to show its ability to observe, assimilate and adapt in the new and highly demanding market standards. There is no need for profits minimization to achieve compliance, as long as a company has optimized its management procedures, minimized bureaucracy, invested in its people as its number one asset, created a safety culture and developed a continuous self-improving system.

[5] Int. Chamber of Shipping (2013)

2 Literature Review

2.1 Quality Management System (QMS)

Quality Management System is a methodology applied on most of the companies around the globe and exists to ensure the consistency of a product or a service provided by the organization. A procedure to oversee all activities and tasks incorporated for the outcome of a company, needed to maintain a desired level of excellence. Its main components are the Quality Planning, Assurance, Control and Improvement, as described by the Association for Project Management (APM)[6]. At this point, it is of high importance to present the distinction between a process and a procedure: A process is a series of related tasks or methods that together turn inputs into outputs, while a procedure is a prescribed way of undertaking a process or part of it. It could be easier, to conceive as follows: a process describes 'what to do', while a procedure is about 'how to do it'.

Explaining the four (4) main components, every end product or service provided (in case of shipping, it is a service provided), shall be accompanied by a process of thinking about the activities required to achieve the desired outcome (**planning**), by a way of preventing mistakes, irregularities and problems (pollution or safety compromisations, for example) during the delivering solutions or services to customers (**assurance**), by a process which entities review and focus on fulfilling the quality requirements of the service delivery process (**control**) and finally, by a process which ensures the constant development of the above procedures (**improvement**).

One of the most important quality standards, is the ISO 9000, which constitutes a family of standards that indicate the basic requirements that any certified company or organization must fulfil in order to analyze, develop, maintain and implement an efficient and effective quality management system, as per ISO (2009). It was first put forward by the International Organization for Standardization, Geneva, in 1987, for the purpose of developing industrial standards that facilitate international trade. The guidance and basis given by the standard, aim towards great management practices and requirements to assure that customers' demands are met accurately by the respective products or services. Concurrently, provide a scheme for measuring the company's consistency to its obligations.

As Tari et al. (2012) stated, such standards, do not aim to be a quality control system of the company's products and/or services, rather to provide adequate guidelines for the organization to achieve a high level of formalization and documentation of its main processes and procedures. As far as the successful implementation of ISO is concerned, various studies, in a wide variety of industries have been conducted, most of them converging in a few major factors. Ab Wahid (2012), after analyzing service providing Malaysian companies, came up with a framework in which the ISO 9000 applicability grows. Top management commitment and employee engagement in the implementation was amongst the top parameters, followed by the

[6] https://www.apm.org.uk/body-of-knowledge/delivery/quality-management/

recognition and reward of the employees, an overall culture towards quality, teamwork and of course continuous improvement. Earlier, Boiral (2011) examining ISO certified organizations in Canada, pointed out that a gradual adaptation of the quality standard to the company's goals and workflow, instead of the takeover of a monolithic, voluminous manual to align with, as well as a clear definition for ISO certification in the culture of the company and the managerial support were important success factors.

Exploring potential obstacles in the standards implementation, Heras-Saizarbitoria et al. (2011) found out that the increased documentation may evolve in an elevated bureaucratical burden for the organization, accompanied by the lack of motivation and involvement, mainly due to lack of knowledge, proper communication and absence of human resources management. Later, Kammoun and Aouni (2013), after analyzing multiple Tunisian certified manufacturers, concluded that inefficient communication, poor training of managers and resistance to change, even from the top management were the top contributing factors. Organizational-wise, the most important barriers appeared to be complications during the process identification and the documentation preparation, connected with the long implementation process of the standard.

ISO Standards, regarding quality have changed a lot since its first publication on 1987. At that time, its main focus was on the quality control of the product or service, in terms of proper documentation to achieve that. Later, with the 1994 version, the focus moved to quality assurance and on the accurate processes, taking as a granted that a company which has already survived in the market, has adequate quality control. The 2000 version, focused on the customer, whoever maybe, internal or external, every process must concentrate to a specific output, meeting specific requirements, set by the customer. Then came the 2008 standard, which focused on the organization's performance, having set all previous parameters, the company must focus on improving their processes and procedures, by repetitive cycles of feedback and corrective actions. Lastly, the ISO 9000:2015, focused on business model and the company's expansion toward success.

2.2 ISM Code & Safety Management System (SMS)

ISM code is an international standard for the safe management and operations of ships and for pollution prevention, as described by IMO, (2010). According to IMO, the explicit purpose of ISM is "to ensure safety at sea, prevention of human injuries or loss of life and avoidance of damage to the environment, in particular to the marine environment and to property". The Code came into force in 1998 and since then it has forced the companies to restructure their quality management systems further to just their daily way of doing business, from the perspective of safety. Compliance with the Code is mandatory counter to the ISO 9000, but its character is more generic, allowing companies to develop their own work policies and processes, as far as they are compliant, as stated by Bhattacharya, (2012). That specific feature of the code gives it an important and admirable aspect of being a self-regulating initiative for a company, compulsory though.

Safety Management System is the mean to ensure the proper functionality of a company, in terms of personnel's safety. A modern SMS should be able to adapt in new technologies and upcoming challenges, assisting the company to maintain its course, achieving its goals and be profitable. In case same is not adaptive to new technologies and upcoming challenges, it may be the reason the company will be out of the market, due to excessive bureaucracy and obsolete practices. For this reason, having in mind the constant improvement, a new 'era' of ISM code is coming, and it's the lean approach on documentations and procedures. Lean management system appears to be a balancing factor between procedural thinking of large corporations and simple/experience-based thinking workers with hands on the real and active aspect of any industry, and in case of shipping, seafarers, being onboard. In other words, a lean management system is the mean to achieve the above stated sustainability without compromising profitability.

Risk can be described as a potential for harm or loss, while safety describes the degree of freedom from danger and hazard in a physical activity, situation or condition with the potential to cause harm (injury, death, damage, or mission degradation). It should also be added, that risk co-exists with a potential source of damage or hazard, as per Kumamoto and Henley (1996).

In shipping, companies deal with high risk situations that may expose human resources in great danger and hazardous positions, thus, it is of high importance for a QMS to be able to cope with safety as its sole purpose. That role is played by the company's Safety Management System, or else the SMS. The Safety Management System has the same components as the QMS, but it is directed to safety alone. As per IMO (2010), any shipping company should develop an effective safety management system to assure, the continuous and constantly updated compliance with all mandatory rules and regulations, that all company's employees onshore and onboard acquire competent safety management skills and that all potential risks have been carefully evaluated. It is a comprehensive management system designed to manage safety elements in the workplace, or a series of defined, organization-wide processes that provide for effective risk-based decision-making related to daily business practices.

For a company active in high risk environments, SMS is an imperative adoption to its Management System, as a management tool to incorporate ethical, legal and financial aspect of the shipping industry. As an employer, one has a moral obligation to ensure that activities done by its employees as well as their working environment are safe. At the same time, most of the countries around the world, legislatively require the employer to ensure the safe work environment and activities of its employees. Also, recent studies show a tight binding between the safe management and financial exposure, Int. Chamber of Shipping (2013). Meaning that with less exposure to risk, a company will have to cope with less and more controlled costs, associated with hazard situations or accidents.

While the main purpose of the subject system is to make the company work better and safer, respectively, sometimes, due to use of obsolete models during development of the systems or since the people designing such systems differ vastly (in terms of knowledge, experience etc.)

with those that are in a position to implement them, the result may be the opposite, such as an accident or property loss, due to bureaucratic and not adjusted-to-reality systemic procedures. When not educated workers face extended voluminous books and manuals, and they are required to study and comprehend them in a very short period, while they are asked to fill forms daily, with no previous knowledge or any proper preparatory courses, the result is almost predicted, that these workers will not follow the procedures as they should, but the responsibility ultimately lies in the system's structure. An accident is the result of multiple processes that failed to be applied sufficiently (see Figure 4. Ideal & Real SMS implementations / Source: ICS 2013)

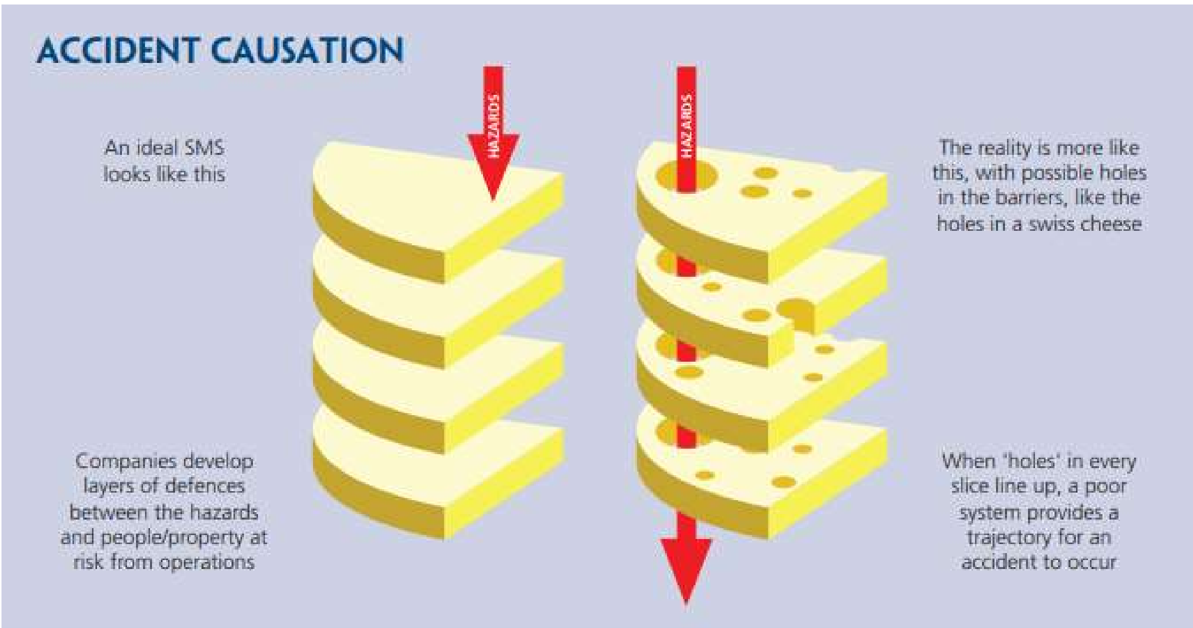


Figure 4. Ideal & Real SMS implementations / Source: ICS 2013

Minahan (1998), stated the fact that service provider such as shipping companies have delayed more than expected to include the quality management into their working procedures primarily because of high difficulty on the measurement of a service failure in comparison to a defective product. He also stated that, at that time the quality management systems were focusing more on the product-based businesses rather than on the service providers, making metrics unusable on services. There was also a lack of IT systems able to handle the needed measurements from all the data created during logistics. But the most important of all, was that there was no agreement of how to define the exact meaning of quality transportation services.

Int. Chamber of Shipping (2013), can be considered as an overview of the previous years, regarding the quality systems used in shipping, as recent high-profile accidents indicate ineffective implementation policies and lack of safety culture within the company. The idea that compliance with regulation is not always enough to achieve safety and pollution prevention is not widespread yet, at the same time, there is a misconception that if a particular type of accident has never happened before; may never occur. ICS through this publication is prompting companies to recognize that investment in safety procedures results in major financial savings and is thus not a 'cost', as it is estimated indirect financial costs of accidents consist an average of three times (x3) those of insurance claims (personnel, cargo damage and pollution). The ultimate target of a detailed chart of responsibilities is to ease the process of locating what went wrong and where exactly the unsafe action began, not to blame, but to correct.

Bringing together recent years of research on QMS and SMS implementation within the industry, Rafik et al. (2014), consolidated the commitment from the top as the cornerstone of an effective safety management technique, while simultaneously sets a goal of 0 accidents as the target for a company's continuous improvement. Research results also show that the majority of accidents involve highly trained personnel which failed to follow, one or more in a row, established procedures, resulting in 1 LTI[7] and 30 minor injuries out of 330 unsafe acts or non-conformities to the system. The total extract of the specific publication is the need of a universal understanding that the safety culture's purpose is not to satisfy the requirements regarding the auditors or the enforcement bodies but to bring actual systematic improvements without fear of reporting incidents.

Using polls on seafarers and a comprehensive evaluation method, by Greiner et al. (2000) & Vieira et al. (2007), a definition of the major complains regarding the ISM and SMS was held by Lappalainen et al (2012), resulting in the overwhelming paperwork and bureaucracy as the number one of the list, followed by voluminous and difficult to read/comprehend manuals (complicated documentation of the management system), irrelevant procedures and finally no perceived benefits by the majority of the procedures. Adding that the way to continuous improvement includes incorporation of the involved-in-the-accident-personnel in the corrective actions and the manual's adjustments, as crucial factor.

Further investigating, the above defects are a result of a system developed depending on incidents and not a proper research and risk analysis, taking into account suggestions and ideas from the seafarers. Therefore, the current ISM code includes unnecessary procedures, which consist one of the greatest challenges of the improvements, a highly dense and complicated documentation, which sometimes (not rarely though) result in procedures with no correspondence to real situations and lack of rationalism. Concluding in an absence of suitable performance indicators due to non-uniform interpretation of the requirements on the respective occasions, despite the fact that KPIs have been introduced to the safety management by Øien (2001) stating that KPIs should capture and represent organizational safety trends and developments.

As was stated by Gonzalez et al. (2016), the 80% of the accidents on vessels are due to human errors which at first may be considered as a rational number for such a hazardous industry, although a further examination on the definition of 'human error' varies a lot in the relevant

[7] LTI: Lost Time Incident, an incident which results in absence from work beyond the date or shift when it occurred.

literature. In their publication, Harvey et al. (2013) which was also appraised by the Chartered Institute of Ergonomics & Human Factor (CIEHF), use the example of the Torrey Canyon, which was a 120,000 DWT oil tanker that shipwrecked off the western coast of Cornwall, England. The shipwreck was at first attributed to a list of human errors and misconducts but in a deeper investigation, the errors could be traced back to management's and equipment's issues, as there was an overwhelming pressure on the Captain by the onshore office and several malfunctions on the autopilot onboard.

Schröder et al. (2010), referred to a big issue within the industry, which is the development of an SMS just to fulfill demands of the regulatory bodies and other interested parties, rather than to create a culture of safety and open reporting, developing two-way communication with the office, getting new feedback constantly. The SMS shall not be a static manual but an adaptive, constantly updated manual, able to understand, monitor and improve how safety works within the organization (Dekker, 2014). The need of an adaptive SMS is not new and has been detected in various publications through the last 20 years, by Flin et al. (2000), Ek and Akselsson (2005), Reason, (2005), Oltedal, (2009), Hänninen et al. (2014), Lappalainen et al. (2014), and recently by Boström and Österman (2016).

It is apparent that the is no lack of knowledge of the system's deficiencies but the will to change and improve it. As it was mentioned by Sampson et al. (2016), in a study conducted by the Seafarers International Research Centre, the 91% of the seafarers stated that documentation demands from on-shore office was increasing of which 59% stated that the increasing documentation has a negative impact on their performance, even though 63% acknowledged the improved safety onboard. Else said, most of seafarers appreciate the benefits of the SMS and the overall additions to the procedures towards a safer work environment, but improvements for adaptability are imperative.

The contributing factors towards an effective SMS implementation are also known at least since Kaynak (2003), in a publication based on multiple studies (more than 4) between 1989 and 1996, concluded that most accurate components of a valid quality system practice were management leadership, employee relations, accurate data and reporting and process management. While Claver et al. (2003), referenced the European Foundation for Quality Management Model, while conducted an extended review of studies concluded that major contributing factors were by far leadership, quality planning, training, process management, and continuous improvement. Next, is Lai et al. (2004), who stated that several factors (10) are proved to account for the increase in the adoption of quality management systems in the logistics industry, amongst them is the top management commitment and the quality measurement, as well as the corrective actions and the continuous improvement. Finally, Talib et al (2013), with their recently published gathering of quality management data from Indian service companies, noted that amongst the main components of a successful system were top management commitment, focus on customer, employee training and education, proper benchmarking and quality culture.

Concluding, in order to have an effective Safety Management System, several components are compulsory, which may be summed up by 5 major processes to be conducted:

1. Definition of the organization's risk profile and key control points in order to develop an adequate Safety Plan, ensuring that every worker clearly understands their safety obligations and his accountability to fulfill the obligations.
2. Definition of the current risk management approach with written policies, procedures and processes, strict documentation describing the required safety behavior, expectations, incident reporting and record-keeping.
3. Creation of direct inter-company communication channels, as well as a Systematic Training and Induction program, depending on the risk-profile of the company.
4. Development of a robust monitoring, identification and review system of nonconformities, combined with the required supervision, ensuring that all risks have been covered by the relevant risk assessment and risk management.
5. Maintenance of adequate methodologies for the proper exploitation of the feedback, two-way communication channels ensuring the adaptivity of a vivid and active safety management system.

Further to the above, it is evident that in order to achieve a high level of employees' efficiency, in terms of processes adoption, as well as an elevated productivity, avoiding loops and do-overs, a strong safety culture is imperative to be built accompanied by increasing safe work environment and continuous improvement through employees engagement in systems changes.

2.3 Lean Management

Lean management can be described as a systematic approach to identifying and eliminating waste in processes. The core mentality of lean is the maximization of value added to the product or service provided, from customer's viewpoint. A lean organization is able to comprehend the customer value and focus on how to guide its key processes to achieve a constant increase of value while producing as less waste as possible, as per Lean Enterprise Institute (2018). As lean has only been applied in production lines and manufacturing, until the end of the last century, with the initiative of Toyota Production System (TPS), there is a misunderstanding that lean does not apply in other industries. In fact, lean is applicable in every business and process, as it is not a certification or scheme to reduce a company's costs, but a mentality which the company will have to be devoted in.

With the aid of the study conducted by Holweg (2007), the concept of lean can be summarized as six (6) major components, or mentality changes to be performed:

1. **Just-In-Time (JIT)**: address the elimination of unnecessary loops and procedures contained in a process, or else, the assurance of a continuous flow of a process's output, as it was first expressed by Ohno (1998).

2. **Perfect Quality**: has to do with the accomplishment of the best possible quality in the product or service provided, with the aim of perfection and unceasing optimization, introduced by Womack and Jones (1996) and further discussed by James-Moore and Gibbons (1997) and Ahlstrom (1998).
3. **Team Management**: Creation of a strong and stable culture in which the organization will respect and assign responsibility to its employees, working together as a team to achieve exceptional results. Teamwork is a skill that has to be learned. As per Liker (2004), in his extensive research in Toyota management practices.
4. **Elimination of Waste**: Defining waste as any action or non-value creating addition in the workflow, Womack and Jones (1996). In other words, waste can be explained as any step of a process that customer is not interested in and not willing to pay for, as per Skhmot (2017)
5. **Continuous Improvement (CIP):** The benefit of learning through relentless reflection and an ongoing effort to improve products, services or processes. Having established a set of stable processes, using CIP means in order to locate and confront roots of inefficiencies. Or, as per Liker (2004), "learn by standardizing the best practices, rather than inventing the wheel with each new project".
6. **Visual Management:** Can be described as the link between the data and the people, use of visual signs to compress and present accurate and status-descriptive information to those who will be able to assess and act accordingly. Visual management aims to give a concentrated form of data make somebody aware of the workflow condition, by merely looking at indicators, as per Liker (2004) and a further review of Christoph (2016).

The above 6 elements are the foundations of Lean thinking, but as per Womack and Jones (1996), in their effort to explain lean, just before a company decides to transform into a lean organization, there are 3 business issues that have to be pinpointed and thoroughly analyzed, in order to achieve a customized transformation. These issues can be summed up by the 3 Ps, or Purpose, Process and People. These 3 words, along with their respective explanations for each business entity, are capable to fully guide its way to Lean (see Figure 5. The 3 Ps of Lean Thinking / Source: https://www.lean5.fi/)

<u>Purpose</u>: is about understanding the needs of the customers and formulating strategies respectively, while constantly adjusting approaches to achieve an output as close as possible to the customer's demands. For a company, to know what exactly is pursuing to accomplish is the number one priority.

<u>Process</u>: is about developing business management discipline to materialize the purpose. Total disposal of wastes, overburden and irregularities in the management system. Added value shall be distinctive at all stages of production of end-product, otherwise adjustments are needed. Standardization and visualization of the final outcome constitute a critical part of subject definition.

People: is about management the company's most important asset, its employees. Strong engagement and association with CIP, while building a culture of teamwork and unity. Employees must be enabled to develop self-awareness in the organization, which will lead to effective team management and communication. On the other hand, managers should be capable of deeply understand the work process, live the company's philosophy and be teachers/inspirators for newcomers. Liker (2004), explaining why Toyota is the No. 1 carmaker, stated that a successful organization should grow its leaders from within, rather than buying them from outsiders.

Figure 5. The 3 Ps of Lean Thinking / Source: https://www.lean5.fi/

Concluding, a prerequisite for an effective implementation of the above is the support and understanding from the top management, their commitment to become a lean and efficient organization, which sets its goals, financial or not, based on a long-term philosophy, even when short-term goals have to be sacrificed. The core of any such initiative shall begin by the change of culture, especially when the organization is a global, multinational entity.

3 Methodologies

In order to achieve a high level of ISM Code implementation in a company's Safety Management System, it is extremely important to have in mind the scope of the manuals that will be developed, their life span, who they are addressed to and what is their aim. A company's SMS is not made to be static, as the regulations are expected to change often, along with the general framework of their applicability along the worlds' fleet. As a result, it is mandatory to develop a system which will be customized to the company's strategy, will reflect the mindset of its personnel and owners and, above all, will be fit-for-purpose and efficient. The ideal SMS would have the ability to change constantly, to adopt all changes by the time they come up, while at the same time would be dynamic in order to assimilate experience gained from daily operations, to avoid the same mistakes happening again. In parallel, there would be no stagnation in its changes, no waiting time from approvals and reviews, and the personnel would have immediate access and willingness to apply, new entries.

All the above 'requirements', profile an ideal SMS, which of course, stands far from where the market is today. As the times change, cultures and mentalities should change with it also. Market has showed multiple times that a company shall be adaptive to challenges and changes in order to survive and be profitable. In the case of a shipping company, adaptability and adoptability of change is more crucial than any other industry, since human lives, potential grand scale pollution and expensive properties are at stake. An efficient methodology for the development of adequate safety procedures is mandatory and the suggested one is Lean Thinking.

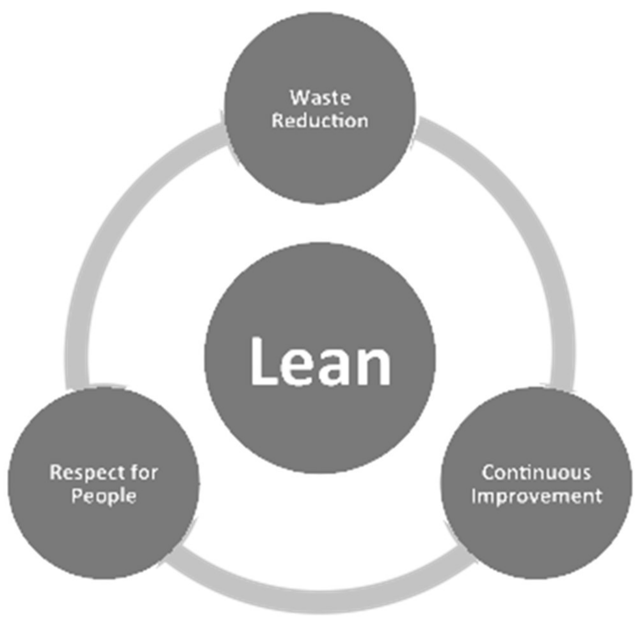


Figure 6. Main Characteristics of Lean Management / Source: Author

Lean Thinking is a superset of mentalities, a shared attitude within an institution, which aims on delivering value, with increased respect for people, waste elimination in every possible aspect, great transparency, effective in both change adaptation and adoption, all these in a framework of continuous improvement (see Figure 6. Main Characteristics of Lean Management). Teams characterized by lean thinking, tend to utilize and blend a variety of sub-methodologies, depending on the organization or the environment applied, having always as an objective the common interest for the best and most efficient outcome.

3.1 Lean Approach of SMS

Today, a shipping company, due to its nature, has two different approaches of management, the ISO 9001:2015 and the SMS, which is based on the ISM Code. While the SMS focuses on strict procedures in order to achieve high levels of safety and risk minimization, the ISO 9001, focuses on the efficiency of the procedures and how they react with each other, enhancing the continuous improvement of the work processes. But how could a company have high safety standards without continuous improvement (Lessons Learned, as per ISM Code), or efficient procedures without the minimizations of risks involved?

Figure 7. Safety Management System within the context of Lean Management / Source: Author

Close examination of the two management methods, could prove a very strong relationship, as they appear to be fully complementary and mutually reinforcing, resulting in a compact and integrated combination of highly effective management method (see Figure 7. Safety Management System within the context of Lean Management). The connecting link appears to be the lean thinking and the mentality of 'getting the highest quality of service or product, in the shortest possible time, using fewer resources, with as less as possible waste' (Taiichi Ohno, Japanese Industrial Engineer). Lean management focuses on the elimination of procedural waste, the just in time foundation to ensure the continuous flow of work, the human resources management with respect to team responsibility, the visual management to guarantee the correct flow of activities and finally the perfect quality along with the continuous improvement.

There are multiple combinations that can be used during the merging period of Lean Management with the ISO 9000 and the SMS, but one should always have in mind that there are two main cases:

Case 1:

A well established and long living company should proceed with the gradual change of its culture, through years of investment in education and training of its personnel, while at the same time, performing a restructure and progressive assimilation of the lean mentality to its procedures; by identification and replacement of bureaucratic and slow moving work-flows. The key to effective implementation may not always be the amendments of existing procedures with another, though, it may also be its total obliteration[8].

Case 2:

On the other hand, for a 'young' and less experienced company, with views for increased efficiency and productivity, it is smarter to build a management system from scratch, rather than a quick transformation of an 'off-the-shelf' management system.

All the above shall be monitored and guided by an experienced, innovative and creatively thinking, consultant or project manager.

It is apparent that the resulting 'management-mix' seems tempting, but the implementation of such changes must be done with great caution. The suggested methodology is inspired by the extended guidance for lean transformation, provided by 'The Toyota Way – 14 Management Principles from the World's Greatest Manufacturer (2004)' and will be called Lean Transformation, divided in 5 Stages, and is applicable in the **Case 1**.

3.2 Lean Transformation

3.2.1 Stage 1: Customer – Added Value

The target of this stage is to identify and outline what is aimed to be achieved, as the output of the 'transformed' process. First, an accurate description of the existing process, on why it is not adequate and detailing its weaknesses. Next, an illustration of how this process would ideally be, thorough description and analysis on where lean thinking can be applicable, along with a presentation of the potential results and the projected applicability, given the existing sources, funds, facilities, installations etc.

In case the projected applicability of the lean transformation is reduced, already by this stage, it is of high importance to mention why and what other sources would be required in order to

[8] Hammer, M. (1990). Reengineering work: Don't automate, obliterate. Harvard Business Review, July-August 2-8.

achieve 100% implementation, an addition to what are the possible implications, limitations and expected bottlenecks.

Continuing, the 'customer' of the process's output must be clearly defined, so that the transformation will be able to match his expectations. Is the customer internal or external? If he is internal, it means that the output of the process is the input of another one, and in that case his feedback in the methodology is almost mandatory. Definition of the added value of the process is another important step of this stage, while the aim is to make the components as lean as possible, there are various factors, both monetary and qualitative, that should be taken into consideration. Such as, how often will that process take place, how long will its execution last, what are the needed funds, which is the desired form of the output, the density of information, its simplicity, the level of confidentiality, potential legal implications, and other relevant aspects.

It should be noted, that even if this stage is preparatory, the goal setting of a methodology is as important as the result. Poor approach, with inadequate feedback from all related parties, at this stage will cause decreased suitability for its purpose. The customer, internal or external, desires a perfect combination of Time – Quality – Cost, known as the Iron Triangle (Figure 8. Iron Triangle / Source: https://medium.com/), **Atkinson, Roger (1999)**.

Figure 8. Iron Triangle / Source: https://medium.com/

3.2.2 Stage 2: Process Waste Identification

At this stage, follows the process's breakdown, to analyze its contributing procedures. The target is to identify all procedures that take place for the process to give the final output. After identification, a thorough analysis to each and every one, must be done, distinction between procedures that are repetitive, time/sources wasting with no substantive importance and those that are important, one-of-a-kind and value adding. It is not uncommon, especially for grand scale companies, to have multiple extremely bureaucratic procedures, because the existing process has been the common method for doing something, and the personnel is used to that, thus, the system is not adapting to the new technologies, due to normalization, or because no one wants to disrupt the continuous, yet time wasting, workflow. Another important investigation is to find overlapping procedures, that may contain partially or completely the same information, collected by different sources, or perhaps checks and verifications that may happen more times than it should, consuming manhours and funds.

In case there are any overlapping procedures, it is important to analyze how and if it is possible to merge them, considering potential legal issues and obligations, top management's decisions, markets' or clients' requirements, possible consequences and effects to all relevant stakeholders. It may be impossible for two overlapping procedures to merge, due to the above reasons, but an intelligent approach may lead to an alternative procedure, fulfilling stakeholders' or others' requirements, incorporating the lean thinking at the same time. Simplicity is a fundamental aspect of lean, thus, one should always have in mind that the perspective and the scope of each systematic change should be guided by the mentality of fit-for-purpose and 'less is more'. Waste identification is the main part of this stage and must be considered as the ultimate goal of every successful lean process (see Figure 9. The 8 Wastes of Lean / Source: https://theleanway.net/)

Figure 9. The 8 Wastes of Lean / Source: https://theleanway.net/

Documentation of procedures is also a heavy burden and a usual 'enemy' of lean thinking. Voluminous descriptions, meaningless and unnecessary materiality should always be avoided; the manuals' aim is to be understood by its users. Difficult and academic language may represent an educated professional, who wrote the procedures' manuals, but if it is not understood by the worker who will be hands-on the job, there is no added value. Therefore, common language is mandatory. Clarity and directness are always indications of a successful description, using the appropriate terminology and addressing to those that will actually perform the operation.

Lastly, before proceeding to the next stage, all related parties, must verify that the means used for the implementation and execution of every process are the most efficient and effective, ensuring their appropriate use also. (e.g. new technologies, computers, innovative techniques etc.). The technology/sources used must be reliable, thoroughly tested that serves people and relevant processes. If the means are not adequate, it should be documented why and if their use is not appropriate, relevant training courses on employees, should also be conducted.

3.2.3 Stage 3: Procedures & Added Value Mapping

The key of the methodology is at this stage. Following an extensive analysis of the process and their respective contributing procedures, it is mandatory to define at what step of the flow the real value is added. In order to do that, the flow of information/product should be mapped in detail, allowing the working group to distinguish the value distribution within the procedure, along with the sub-procedures and their correlation. An Added Value vs Time graph in manufacturing industry, is depicted below, showing the value distribution during the process, using the Smile Curve, Stan Shih (1992). (see Figure 10. Smile Curve - Added Value Vs Time and Different Departments / Source: https://iiot-world.com/)

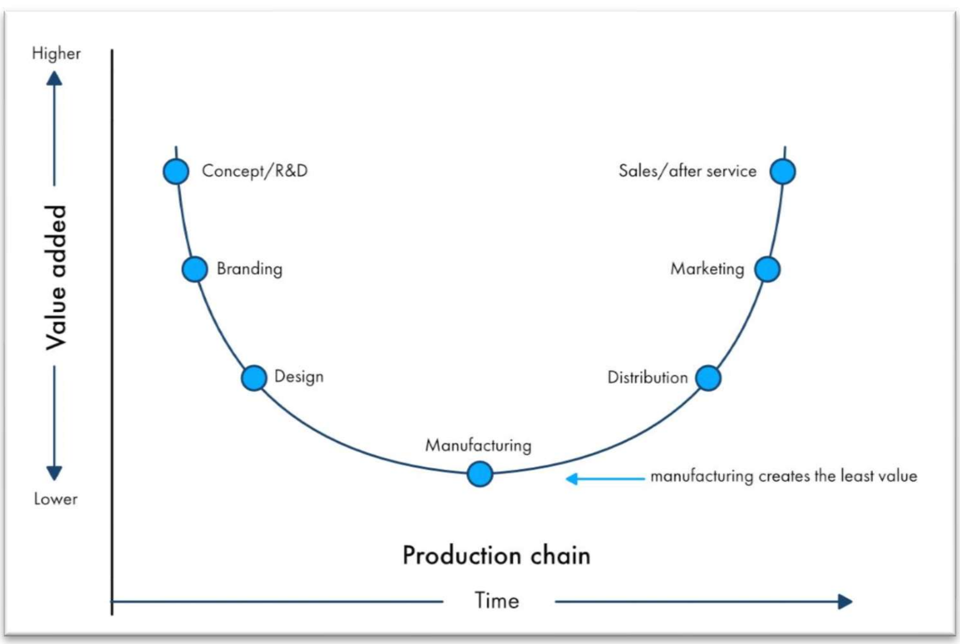


Figure 10. Smile Curve - Added Value Vs Time and Different Departments / Source: https://iiot-world.com/

Checks and verifications must take place, ensuring that the selected, by stage 2, processes are those that carry the added value. How many are they? Are they clear to distinguish? Is it possible to merge them even more without losing their purpose? Another critical part is the visual/documented verification of in-time quality/quantity control between the steps. A well-designed process will allow its operators to determine immediately whether they are in standard condition or deviating from it. By not having the proper filter and alarms to be notified promptly, the inaccurate output of a procedure will be the erroneous input of the next one, causing excessive repetition and loops at later stages of the process, when the cost can be even greater.

Loops and do overs must be avoided at all costs, having in mind that the processes will be misconceived at some point, it is essential to minimize repeatability. The outcome of the methodology must be a continuous process flow, combined by routine checks and inspections, building a culture of fixing problems instantly, getting sufficient quality the first time. The long-term productivity perspective dictates to stop or slow down in order to achieve excellence, by the time any defect is detected.

Next, having defined the minimum added value of the output, from stage 1, it is essential to measure and calculate the minimum related cost, which means both direct and indirect costs. (e.g. from a manhour lost, it is not enough to calculate the cost of manhour, but also the consequences of the mistimed desired result on the next procedure of the workflow). Various parameters have to be taken into account, neither 'in-time' nor 'high-quality' delivery is enough by its own, it is crucial that those two are combined. (e.g. in data processing, a procedure must ensure that the right amount of data will be ready the right time with the requested margin of error, all these combined).

A workflow graphical representation may assist a lot during this stage, by incorporating as many as possible related parties, focusing on the exact depiction of the actual workflow, including all mistakes, faults, omissions and do overs.

3.2.4 Stage 4: Creative Brainstorming

Creative Brainstorming is when the transformation is beginning to formulate. Having described who the customer of the end product – process is, what is he expecting and other parameters set, by stage 1, having classified 'waste introducing procedures', and 'unique procedures', by stage 2, and finally having identified the distribution of the added value within the procedures while at the same time avoiding loops in the workflow, by stage 3, it is time to think creatively, inventive and forward-looking towards the most efficient and innovation-adaptive ways to transform the existing processes.

Working groups shall be created, performing relentless brainstorming, feeling free to express ideas for processes optimization. It is imperative, for the success of the methodology, for all the micro-stakeholders[9], to take part, giving their precious feedback and advising for how all these

[9] Micro-stakeholders: Stakeholders of company's microenvironment. The totality of people and other connected groups of people/organizations that are very close to the business or the department, and which all have a direct and measurable impact upon the customer experience. Customer may be internal or external.

changes will affect their workflows. Simplicity is essential to be the perspective of all potential solutions, of course keeping the goal of the process intact, with no compromisations at all.

At this point, it is necessary to mention, that the creative brainstorming has hundreds of possible methodologies to be applied. Having always in mind that all related parties should be given the opportunity to express an idea, not only experts, managers and top management, but the uneducated personnel also. The presence of the hands-on-the-process personnel is mandatory, as people with years of experience, tend to have great ideas in optimizing their daily tasks. Of course, outsiders and other relevant experienced parties, should be more than welcome to offer their 'helicopter view' of the situation at hand. (e.g. retired personnel, consultants, analysts, suppliers, vendors etc.)

The next step of this stage is the filtration of the ideas that have been placed 'on the table'. This step constitutes one of the most difficult parts, as the evaluation of the ideas is imperative to be done with caution, well-calculated but disruptive and revolutionary, all these in the philosophy of lean (see Figure 11. Filtration of Ideas using Previous' Stages Outputs). The initial filters that should be used, are the parameters that have been set in the Stage 1, which will ease the efforts by percolating ideas with reduced applicability and potential implications (e.g. legal issues). It is also possible that multiple solutions will arise, therefore, further filtration can be used, adding more constraints or deeper analysis (e.g. cost effectiveness analysis).

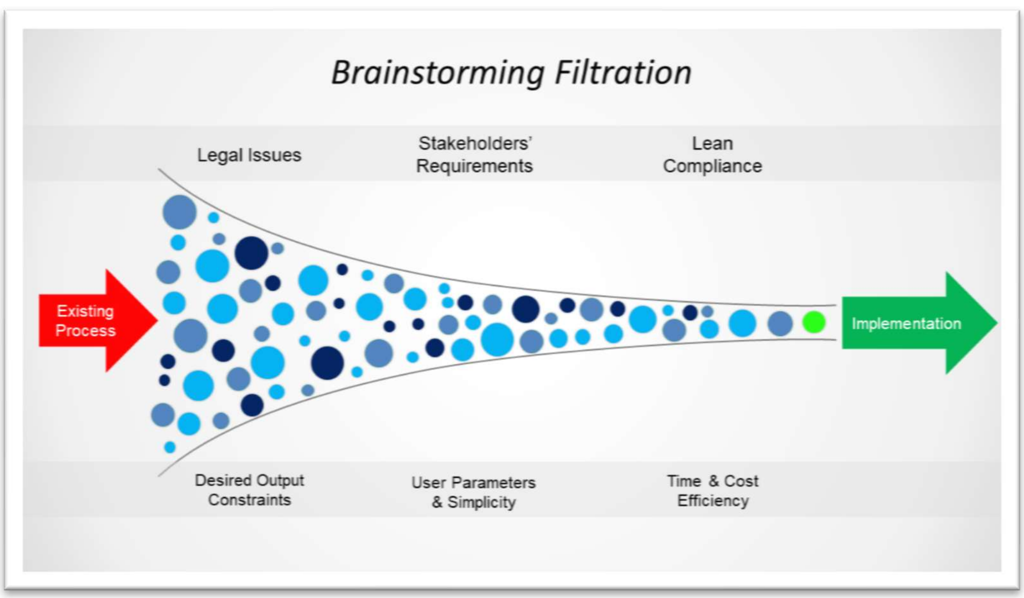


Figure 11. Filtration of Ideas using Previous' Stages Outputs

Source: https://www.marketingteacher.com/

3.2.5 Stage 5: Implementation

After a creative brainstorming and a thorough consideration of all options and alternatives, chosen approach of transformation is ready for implementation. Lean thinking dictates to take enough time for making decisions, considering all options and choices. The 4 previous stages aim to discuss problems, potential solutions with all that are or will be affected, collecting their ideas and perspective. It may be time-consuming but increases the probabilities for a more efficient and adaptive solution, while at the same time, prepares the 'stage' for rapid implementations and quick employments.

An implementation of the stage's 4 chosen idea should take place, followed by the necessary verification and validation. By these terms, based on the PMBOK guide (2008), is meant:

Verification: The evaluation of whether or not a product, service, or system, in this case is a system, complies with a regulation, requirement, specification, or imposed condition, as set by Stage 1 of the present methodology. It is often an internal process, which translates that the change should run in a pilot application, in a smaller scale, to prove its capacity to withstand a grand scale function.

Validation: The assurance that a product, service, or system meets the needs of the customer and other identified stakeholders. It often involves acceptance and suitability with external customers. In this case customers may be other departments of the company, or external bodies, which share the need of the subject change or require the process's output as their input in the overall workflow.

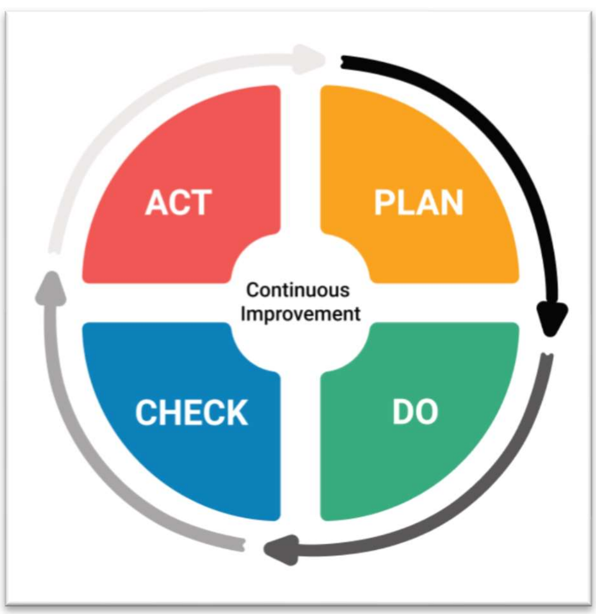


Figure 12. Plan - Do - Check - Act Cycle to achieve the continuous improvement / Source: https://kanbanize.com/

A process, having been verified and validated, is ready, in terms of applicability. It is mandatory at its first steps to be closely monitored, allowing users to give their feedback for further improvements. The way lean mentality suggest to monitor the application of the changes is an iterative management methodology used for the full control and continuous improvement of processes, known as **Plan – Do – Check – Act** or PDCA (see Figure 12. Plan - Do - Check - Act Cycle to achieve the continuous improvement / Source: https://kanbanize.com/). The evaluations of the results of every cycle are beneficial for all related parties and is suggested to be shared and thoroughly studied for further analysis and actions to be taken. Interviews with the first personnel that incorporated the new and lean-transformed processes for further feedback collection, is recommended and could prove to be valuable.

Further to the implementation, and using the PDCA, a selected working group shall continue to monitor the performance of the newly introduced process, regularly assessing the results and inquire for comments by the users. Next, after completing a full working cycle, the process may be further adjusted, by repeating the methodology from Stage 1, again. Lean Thinking is a superset of mentalities and one of its most important subsets is Agile. Agile Project Management is recommended to be the methodology for quality management system's maintenance, by running continuous cycles of the Lean Transformation methodology.

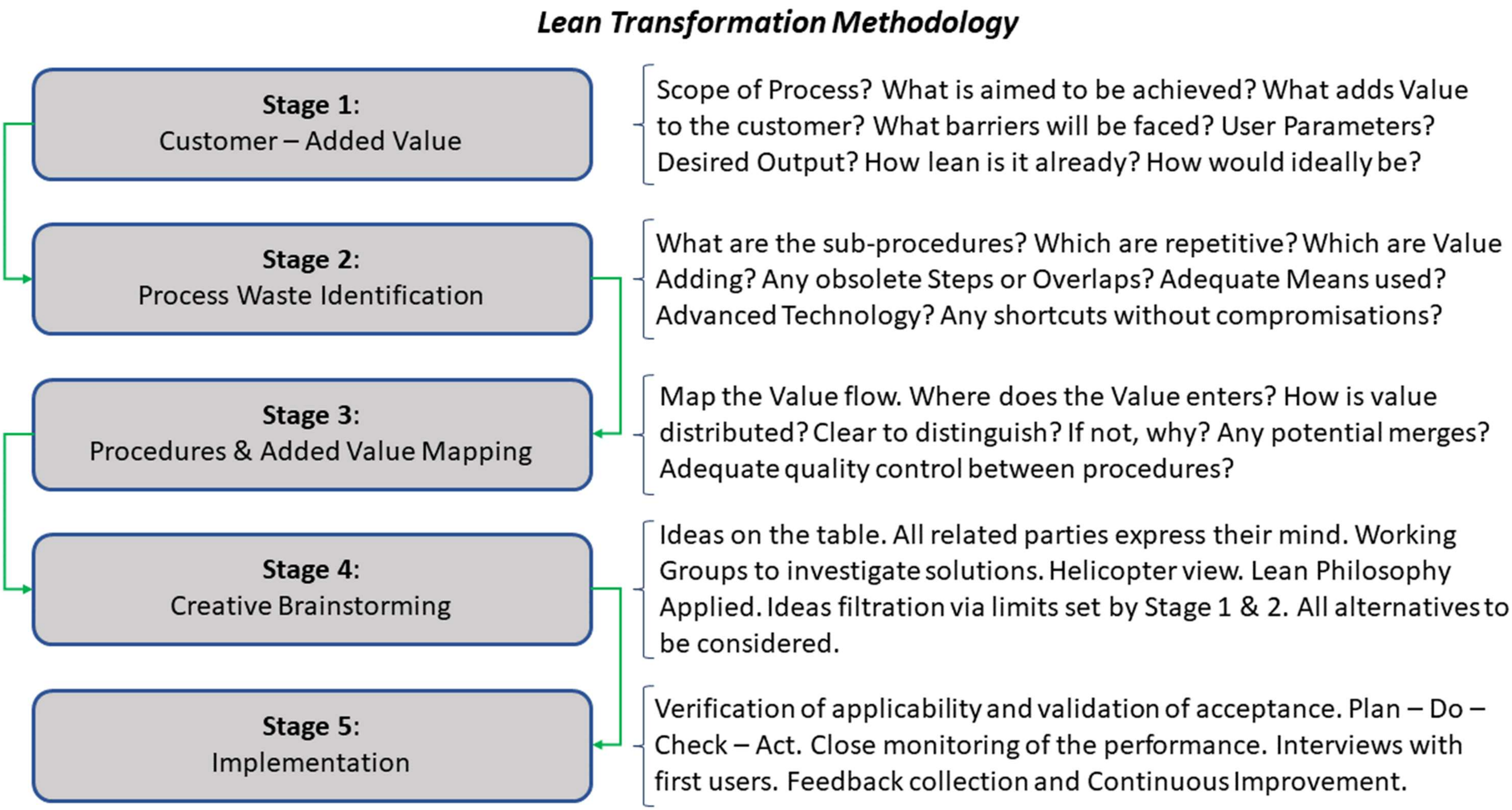


Figure 13. Schematic Diagram of Lean Transformation Methodology

3.3 Agile Project Management (APM)

3.3.1 Introduction to APM

Agile is an adjective that describes the ability to move quickly and easily, increased mobility and astuteness. In business world such abilities are almost imperative to guarantee the sustainability of each entity which competes in post-2000s markets, incorporating high volatility, unsureness and are totally unpredictable due to the uncountability of variables. Being agile is a challenging task for a shipping company, especially a globally active one, which translates to multiple different laws, international regulations, contradicting trade-schemes, demanding human resources planning and asset management procedures.

For an organization, agility means to be able to create and respond to change, dealing with and succeeding in an uncertain, potentially hazardous and turbulent environment, such as the shipping industry. The first industry to introduce that approach was the Software Development, as programmers realized that the way they were building the software was not working for them, as they had to go back and forth multiple times in order to satisfy the customers. They started exploring ways to blend customer's needs with the real-time development in order to avoid unfit for purpose final products. The methodology they came up with, embodied close collaboration between development team and business stakeholders (customers etc.), frequent delivery of business value, in tight and self-organized teams, along with intelligent ways to develop, confirm and deliver code.

The real innovation was the focus on people doing the work and their collaboration to provide solutions with cross-functional teams, by utilizing the appropriate practices of each one's context. Later, in 2001, the methodology was formally expressed by the Manifesto for Agile Software Development (2001). Its main approach was that individuals and interactions shall be over processes and tools, a working version shall be over the comprehensive documentation, customer collaboration shall be over contract negotiation and quick response to change shall be over the following of an initial plan. A project management methodology that uses short development cycles called "sprints" (see Figure 14. Short Development Cycles called 'sprints' / Source: https://www.meistertask.com/), to focus on continuous improvement in the development of a product or service.

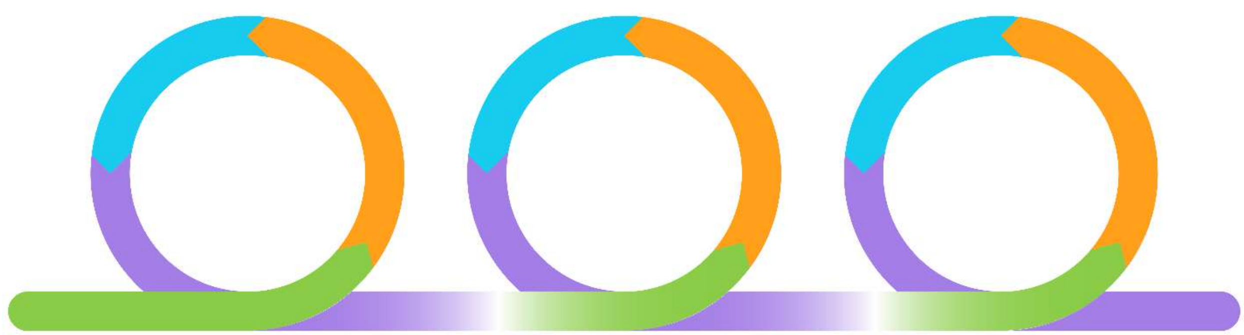


Figure 14. Short Development Cycles called 'sprints' / Source: https://www.meistertask.com/

Such mentality is part of the lean management approach on project management, in other words, they both incorporate mottos such as ‘focus on value’, ‘elimination of waste’ and ‘small batch sizes’. The goal of all these procedures is the optimization of the project management, with the best results with the least effort spent and the most efficient working cycles. The Venn diagram below depicts the correlation of the two philosophies (see Figure 15. Agile Project Management is subset of Lean Management / Source: Agile Practice Guide, PMI 2017)

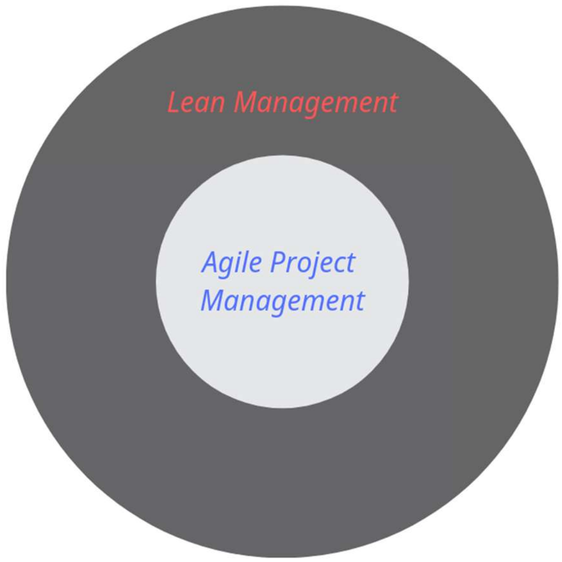


Figure 15. Agile Project Management is subset of Lean Management / Source: Agile Practice Guide, PMI 2017

As was described by Agile Practice Guide, PMI (2017), new designs, problem-solving and not-done-before work is fully exploratory which translates to high level collaboration and reflection needs by the responsible team. Usually, more definable works are automated but the more the uncertainty increases the more difficult the automation becomes. Such projects involve high rates of change, complexity and risk, areas where common-used predictive approaches fail to determine the requirements, resulting in unfit-for-purpose final products. At the same time, agility explores the feasibility in very short feedback loops, frequent adaptation of processes and reprioritization, regularly updated plans and frequent delivery.

As a method, it is highly applicable to project that require research and development, have high rates of change, unclear/unknown, constantly changing requirements and that have a hard-to-describe goal.

Agile management is mainly described by 12 major principles, as per Manifesto for Agile Software Development (2001):

1. The highest priority is customer’s satisfaction through early and continuous delivery of valuable software.

2. Change of requirements is welcome, even in late stages of development. Agile processes harness change for the customer's competitive advantage.
3. Deliver working software frequently, from a couple of weeks to a couple of months with a preference to the shorter timescale.
4. Businesspeople and developers must work together daily throughout the project.
5. Build projects around motivated individuals. Give them the environment and support they need and trust them to get the job done.
6. The most efficient and effective method of conveying information to and within a development team is *face-to-face conversation*.
7. Working software is the primary measure of progress.
8. Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely.
9. Continuous attention to technical excellence and good design enhances agility.
10. Simplicity--the art of maximizing the amount of work not done--is essential.
11. The best architectures, requirements, and designs emerge from self-organizing teams.
12. At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly.

These major principles, mainly referring to software development context, describe the fundamental mindset behind being agile.

3.3.2 APM Application to Other Industries

Software Development industry appeared to be only the beginning for implementing such practices, as in recent years, further from Technology sectors (25%), many other industries followed with an increasing rate. It appears to be a highly adoptable method for project management and the markets' trend prove it (see Figure 16. Industries Adopting Agile / Source: 13th Annual State of Agile Report).

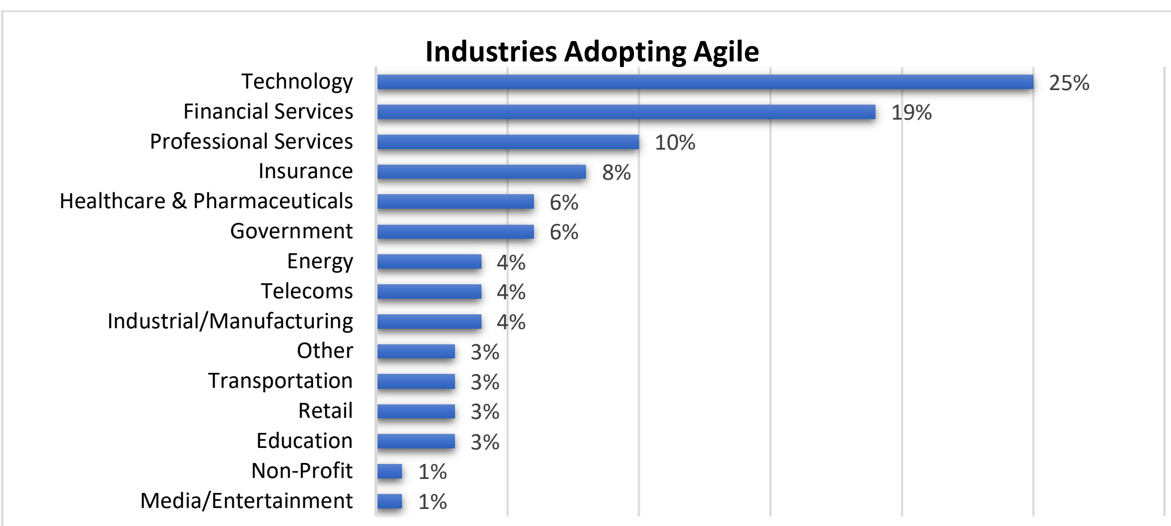


Figure 16. Industries Adopting Agile / Source: 13th Annual State of Agile Report

In the latest market survey, it was shown that last year the companies selecting agile methodologies aiming to reduce project cost have been increased by 71%. Concurrently, the companies that reported reduced costs due to agile implementation have been increased by 27%. As shown in the 13th Annual State of Agile survey, by Version One (2019), the main reasons for adopting Agile mindset in the way of doing business, the above industries vary a lot (see Figure 17. Top Reasons for Agile Adoption from a Company).

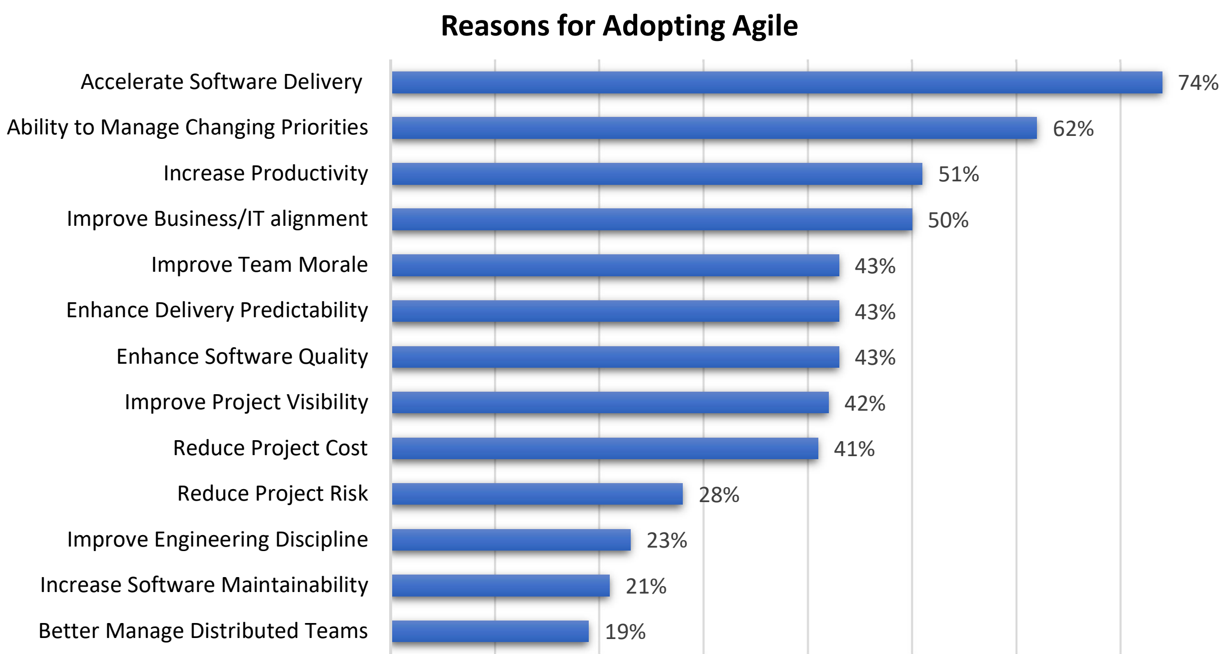


Figure 17. Top Reasons for Agile Adoption from a Company

Increased efficiency and adaptability seem to be the fundamental components of agile project management, while there is space left for new designs, innovation, high degree of freedom within the team, maintaining its strict engineering procedural approach with the use of short feedback loops. The acceptance from multiple industries, shows strong characteristics of an adjustable methodology, complying to multiple standards and requirements without compromising the ultimate goal, the project's completion. In other words, agility may provide a strong contingency measure against bureaucratic procedures, holding back multiple projects resulting in slow moving organizations, lacking adaptability.

The major benefits of the specific management tool are that it reduces waste and rework due to constant feedback channels aiming for the fully customized products or services. Its success level may be attributed to the frequent adaptation of processes, the continual reprioritization and the regularly updated work-plans inclusive of frequent product or service delivery.

3.3.3 Lean Transformation Using APM

As it is stated in Lean Transformation, Stage 5: Implementation, a successful transformation of the process shall never be static, but continuously improving. Using agile project management, the working group will be able to constantly have a working version of the process, while at the same time will be able to collect feedback, plan improvements, do them, check their results and the same again, in sprints, as APM dictates. All the above, address the case 1, a company which already have a QMS, with plan-driven processes and desires to transform its system to be lean and adaptive in change.

A company's SMS is as a living organism and shall not be considered as a static documentation but more like a constant effort to, document safety procedures, include everything that could go wrong, reduce energy consumed by the machineries and protect the environment. The perfection of such system could never be reached, due to its complexity, but this is the reason all related parties must ensure its continuous improvement. Its development must be dealt as an extremely uncertain work, the kind of projects that we are unable to automate yet. As a result, the agile project management approach is suggested, not as the best solution to the problem, but as an aspiring and potentially efficient method to incorporate all stakeholders' needs while maintaining its 'safety-first' character. In the case 2, with company which is new in the market, about to begin its system documentation and management processes from scratch, agile methodology can be very useful, minimizing risks, while maintaining a forward-looking and cognitive aspect.

The design process of every Safety Management Systems consists of four (4) important parameters, which can also be called '4 pillars of SMS', as per Thackery, VP of the American Medical Response (AMR). The three main components are safety risk management, safety policy/leadership and safety assurance, which are linked together by the final component, the safety promotion. Explaining, safety policy establishes the top management's commitment to continual improvement of safety, constant definition of methods and processes, along with organizational restructuring needed to meet safety goals, while safety risk management determines the need and adequacy of risk control means together with their respective effectiveness. Next, safety assurance evaluates the continued effectiveness of the implemented risk control strategies, ensuring that the outcomes will be the expected, compliant with the regulations and provide enough feedback, while concurrently promotes identification of new hazards and potential sources of unsafe actions. Finally, safety promotion included the essential part of training and communication within the environment, advocating for a strong safety culture though raise of awareness, lessons learned circulation and feedback inputs from everyone.

In order to further investigate the applicability of subject method, a comparison will be made between the 12 major principles of Agile and how they translate for the design of a Safety Management System, which is strongly characterized by discipline. As it is stated by Boehm &

Turner (2003)[10], discipline without agility leads to bureaucracy and stagnation, which both, in the case of a safety management system would result in an accident. The Table 1. Agile Project Management in Software Development and in SMS design below presents the correlation between the two systems.

Table 1. Agile Project Management in Software Development and in SMS design

Agile Management applied in ISM Code		
#	**Software Development Science**	**Safety Management System design**
1.	The highest priority is customer's satisfaction through early and continuous delivery of valuable software.	The highest priority is maritime safety, protection of the marine environment and their continuous improvement, of the SMS.
2.	Change of requirements is welcome, even in late stages of development. Agile processes harness change for the customer's competitive advantage.	Change of Rules and Regulations is frequent, high adaptability is a major concern. Agile processes will allow SMS to adjust with ease.
3.	Deliver working software frequently, from a couple of weeks to a couple of months with a preference to the shorter timescale.	A SMS must always be up and running to ensure proper and safe functionality of the company and its personnel.
4.	Businesspeople and developers must work together daily throughout the project.	Shore and offshore personnel must work together with all related parties. Effective communication is a top priority and leads to a highly effective SMS.
5.	Build projects around motivated individuals. Give them the environment and support they need and trust them to get the job done.	Trust in capable 'designers' is extremely important, as lives are at stake. Useful feedback from experienced individuals and their contribution is indispensable. Mistakes/Accidents must be treated as chance for improvement.
6.	The most efficient and effective method of conveying information to and within a development team is face-to-face conversation.	All related parties must give their feedback to ensure the adequacy and integrity of the system as a whole. Sitting in the same table offshore and shore-based personnel gives precious feedback.
7.	Working software is the primary measure of progress.	A working version of the SMS is the #1 priority, to ensure safe operations at all times.

[10] "Balancing Agility and Discipline: A Guide for the Perplexed", Boehm & Turner (2003), ISBN 0-321-18612-5

8.	Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely.	Amendments, corrections and improvement of the system must always be underway. A never-ending process of advancement.
9.	Continuous attention to technical excellence and good design enhances agility.	Technical excellence, adequate assessment, repeated evaluation and self-criticism shall characterize the design/maintenance team.
10.	Simplicity – the art of maximizing the amount of work not done – is essential.	Bureaucracy constitutes the #1 complain against ISM code. Reducing voluminous procedures is a must to increase efficiency.
11.	The best architectures, requirements, and designs emerge from self-organizing teams.	All members of design team shall be hands on the assignments, even managers and workers. SMS is mainly designed by experience gained from every part of the 'working cycle'.
12.	At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly.	Fine-tuning of the design team, along with field test, should provide enough input for restructures and organizational improvements. The aim is risk minimization at all costs.

The relation between the two is apparent. Agile management can allow processes iteration to be quick and work instructions to be created from the bottom up, not just from the top down, an approach which has proven to be highly effective. At the same time, the organization will stand in a position to judge how much documentation is required, in order to achieve specific goals. Currently it is common that conformance with various quality or safety standards imposes strict and voluminous descriptions of procedures, written by outsiders with limited experience 'in field', this is the case of the 'off-the-shelf' safety management system.

4 Technical Implementation

4.1 SMS Documentation

The ultimate goal of the SMS is the prevention of unsafe actions and potential accidents, and through the years, it is constantly expanding, aiming be more robust and comprehensive, by incorporating more and more feedback from the operations and other activities. The result of this expansion, apart from the benefits of a higher quality safety management, is the rising volume of the system, which eventually may even prove to be a danger for the safety. High volume instructions are not adapted by the community, as it is normal, the crew will not assimilate easily a huge system with hundreds of pages.

Lean Transformation is a process which aims to improve the operation and the maintenance of the SMS, and through multi-layer systematic approach to enhance the acceptability of the system. At first, the transformation aims for making the processes lean, through examination of wastes, overlaps, extended documentation and as a result, significant decrease of the each process' descriptions. Consequently, pages reduction is achieved, therefore, the next stage is to reduce documentation, such as forms and multiple loops of the same procedures (e.g. forms that need to be printed, signed and scanned, instead of an electronic signature). By removing the waste from the processes and reducing the documentation needed, the SMS becomes more accessible and customized to the company's objectives, and stops being perceived as a 'mountain of bureaucracy' that each seaman needs to overcome in order to perform his tasks.

The job descriptions then, become more specific and the KPI are easier to be set, while the measurement of the systems performance can be an automated task. By reducing the time wasted by seamen to study the SMS as a whole, a meticulous segregation of specified processes can be performed, to address each employee specifically, achieving a higher sense of responsibility. The result of that approach is easier, smarter and more effective training, reduction of reading material, focused education and the potential use of online automated systems, while case studies can be perused effectively. All the above, results in a meaningful increase of the system's performance, which is fully adjustable, through the use of KPIs and exudes the mentality of the continuous improvement. The 'end product' of such a system cannot be anything different than less non-conformities, less fines, accidents prevention, increased environmental awareness, legal compliance by nature and external audits' observations to be as low as practically possible. The achievements of the transformation are shown in Figure 18. Achievements of SMS's Lean

At this point, it is of high importance present the overall size of a company's SMS, in order to figure out the great impact of a lean transformation initiative towards its design. By nature, the company's safety management system, is a complete guide of how to act safe, onboard and ashore, when working in a shipping company. At the same time, it is an extensive description of processes and procedure regarding the proper risk management and avoidance of personnel's' and company's assets' exposure in hazardous conditions. Therefore, any such instrument, should be capable to be understood and easy to apply, for all related parties.

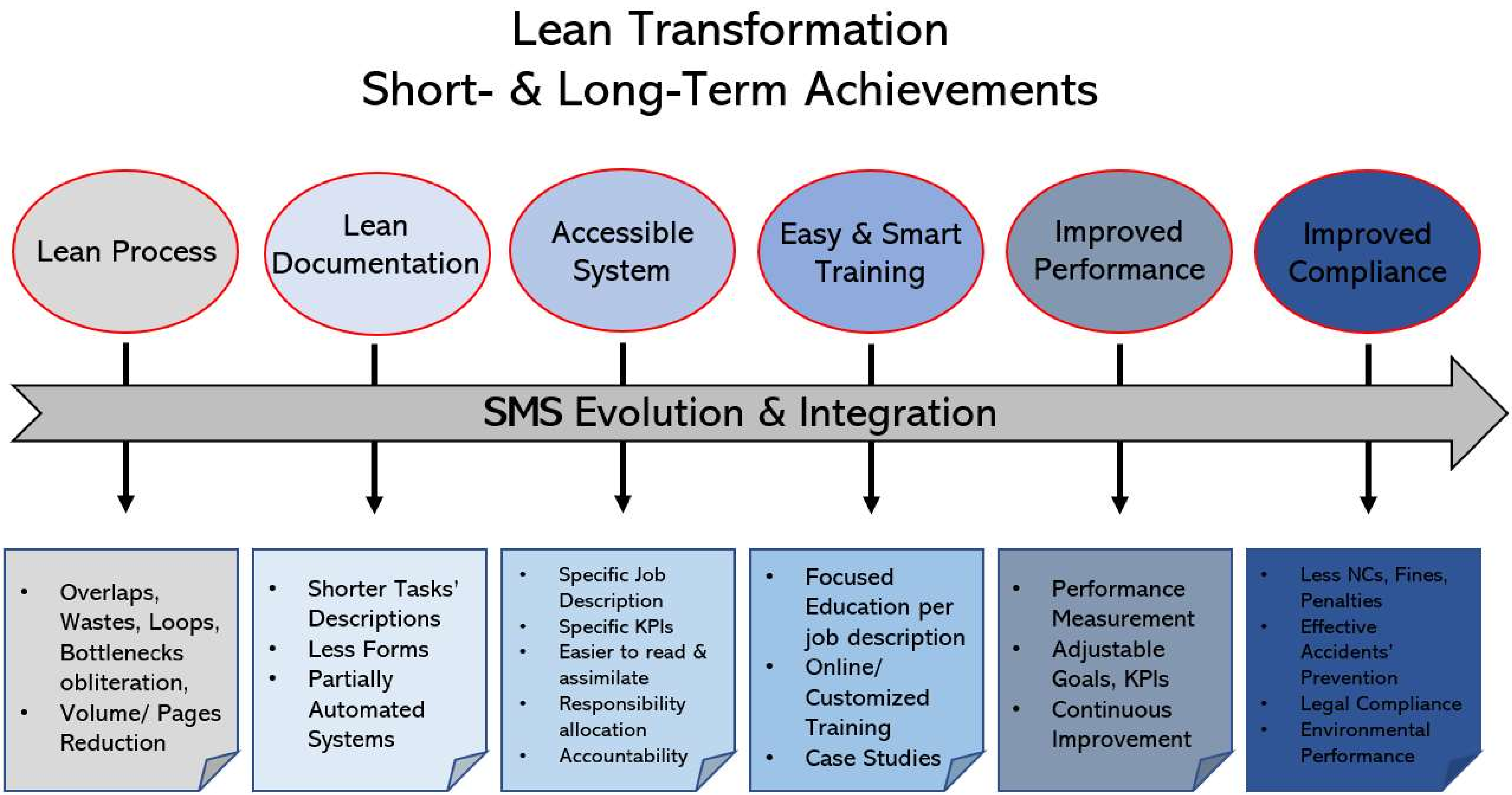


Figure 18. Achievements of SMS's Lean Transformation / Source: Author

Firstly, the safety management system is divided in two main parts, the vessel's and the office's management system. This means that the first describes the operating procedures that crews onboard are required to follow and the second, the office's personnel, accordingly. The documentation part of every SMS is one of the most difficult parts and may prove to be one of its key components, for either a uniform acceptance or rejection from the community. As per ISM Code, all shipping companies shall develop an SMS implementation plan, formally endorsed by the company, to define the company's approach to the management of safety in a manner that meets the company's safety objectives. What is noticed, though, is that subject documentation, is very extensive in a degree that may counteract against safety sometimes.

By applying the Lean Transformation in a company's SMS, the company would shrink its documentation while maintaining the processes and procedures intact, but at the same time, the overall acceptability of the SMS would rise immediately. Today, a safety management system that a vessel and its crew need to have has the structure and volume shown in Table 2. Structure of a Vessel's SMS, depending on its type:

Table 2. Structure of a Vessel's SMS, depending on its type

Manual	**Chapters**	**Forms**	**Posters**
LNG Cargo Operations	25	40	
Cargo Operations - Generic	24	84	4
Oil Cargo Operations	24	2	
Chemicals Cargo Operations	63	19	1
Dry Cargo Operations	20	42	
Containers Cargo Operations	28	39	
Deck Operations	8	9	
Dynamic Positioning Operations	56	21	
Emergency Response Plan	2	6	
Fuel Management Plan	18	9	
Fire Training	12	0	
Garbage Management Plan	3	0	
Navigation Procedures	12	31	4
Inspection & Maintenance	11	42	
Engine Room Operations	14	24	6
Management	12	40	2
Safety Operations	33	34	23
Total	**365**	**442**	**40**
Pages	**7300**	**884**	**40**

It is apparent, that the crew onboard will have to face an average volume of **8200** pages, which translates to almost 23, 350-pages novels, that need to be read and fully comprehended, in order to be compliant and able to execute its guidelines. At the same time, the 8200 pages, are not the only manuals and procedures that need to be read, as each machinery that is placed onboard has its own voluminous operation manual, that every responsible seaman has to study before its use.

The overall volume of the manuals, drawings, plans and guides onboard would result in an average of **16000** more pages, which corresponds to almost 46 350-pages novels to be read.

Parallelly, the office's manual needs to be taken into account also, which has the structure shown in Table 3. Structure of Office's SMS

Table 3. Structure of Office's SMS

Office SMS			
Manual	**Chapters**	**Forms**	**Posters**
Main Manual	37		
Office Manual	73	62	
Health, Safety & Quality Manual	18		
Technical Dpt. Manual	22		
Operations Dpt. Manual	21		
Information Tech. Manual	36	34	
Purchasing Dpt. Manual	18	10	
Crewing Dpt. Manual	15	8	
Account Dpt. Manual	16		
Dry Docking Manual	17	20	
Cyber Security Manual	15	1	
Offshore Office Manual	5		
Total	**293**	**135**	**0**
Pages	**5860**	**270**	**0**

The office's manual, which any of the company's employee is required to have read, consists of an average of **6100** pages, which translates to 18, 350-pages novels, apart from any other complementary documentation, such as vessels' certificates, manuals, plans and drawings. The total documentation of a company's SMS only, which is not the only implementation plan available and required within the industry, has a volume of almost 15000 pages. From the above, and in combination with the various defects observed within the SMS, by multiple authors, as presented in the Literature Review, it is easy to visualize the impact that a proper lean transformation would have to a safety system documentation within a company.

With the scope to provide a better view of the safety management system's documentation defects, various cases where external audits in a shipping company and its vessels have returned with observations, will be presented. One of the most important external bodies that can audit a vessel, is the Port State Control (PSC), which in case of a serious deviation from the law, has the authority to detain the vessel temporarily until the specific matter is closed. On Table 4. PSC detainable observations, multiple cases where vessels have been detained and their respective root causes, with respect to the SMS implementation, are shown.

Table 4. PSC detainable observations

Flag	Finding	Root-Cause
LIBERIA	Engines (ME & AEs) parameters recordkeeping not found in accordance with the verification procedure	Crew failed to update the engines' records after maintenance, due to complicated documentation
MARSHALL	Fire Control Plan found obsolete and not fit for purpose	Inadequate plan's customization on the specific vessel's needs
GREECE	Crew found not familiar with the maintenance and operation of firefighting appliances in Engine Room	Inadequate training and familiarization, due to complicated documentation
BAHAMAS	Emergency Gen. failed to connect to switchboard during blackout simulation tests.	Insufficient planned maintenance
CYPRUS	At least 2 firefighting outfits to be equipped onboard. Outfits found not suitable for firefighting	Insufficient planned checks and maintenance
LIBERIA	The content of training manual onboard is not complete and customized to the vessel	Insufficient documentation
LIBERIA	The sample lines valves of the Oily Water Separator do not have any seals, which is against the company's SMS procedure	Inadequate familiarization with the company's SMS

The content of the above table are only an example of how minor errors and mistakes in the design of the SMS's structure may lead to great deficiencies, such as the aforementioned, which all of them resulted in the vessel's detention from a few hours to multiple days, hence compromising its commercial schedule and the company's profitability. Processes which require excessive documentation is one of the major contributing factors to such cases, as the crew may prove to be insufficiently familiarized, due to inadequate 'studying' of the SMS.

Another important external body that usually audits the vessels, is the Flag, which through Flag State Inspections, ensure that satisfactory standards are being maintained onboard vessels flying their flag. Typically, such inspections are carried out by designated inspectors and include a verification of statutory documents as well as a general examination of the vessel's structure, equipment and machinery, on top of a thorough inspection of operational testing of firefighting/safety equipment and other life-saving appliances. It is obvious that through all that, the flag also inspects the company's SMS implementation, as all the above, in order to follow the requirements, need proper planned maintenance, training and familiarization. The outcome of a vessel's flag inspection is a key indicator of the organization's safety management culture and its implementation efficiency. Below Table 5. Flag Inspections Observations, presents major findings found by Flag State Inspectors, all around the world, that correspond somehow to the safety management.

Table 5. Flag Inspections Observations

Flag	Finding	Root-Cause
LIBERIA	Change-Over procedures from high to low sulfur not vessel specific	Insufficient documentation
LIBERIA	SOLAS Training Manual is not vessel specific	Insufficient documentation
LIBERIA	Firefighting equipment not fit for the crew onboard	Inadequate training and familiarization with the equipment to identify same
MARSHALL	Oil Record Book II not properly maintained	Insufficient implementation of SMS procedures and inadequate training
GREEK	Bunker and Oil Transfer procedures not adequately explained	Insufficient documentation
GREEK	Company's Orders were not adequately circulated to the crew onboard	Major deficiency in SMS's implementation

It becomes more and more clear, that the majority of the observations can be traced somehow to a respective deficiency of the SMS, which will either translate to an inadequate familiarization/training with respect to the safety procedures, or to a non-customized-to-the-vessel procedure, which would mean an off-the-shelf purchase of the SMS manuals. A Lean Transformation would be able to fully adjust the procedures to the respective safety objectives of the company while at the same time would reduce the procedural/bureaucratical waste significantly, automate processes and simplify others.

As it is mentioned before, the safety management system should be considered as a living organism, where its component will have designated procedures to provide feedback for its continuous improvement. Continuous improvement of an organization is measure through the monitoring of the organization's safety performance indicators, as well as its technical performance indicators, and it strongly related to the maturity and effectiveness of an SMS. Safety assurance and follow-up actions, with a combination of lean thinking are able to improve meaningfully the overall performance of the SMS, reducing the workload which stands on crew's and personnel's 'shoulders', due to its extensive documentation. A highly productive Quality Management System is side by side to a highly efficient Safety Management System, and further exploring the complementary aspects of the two systems, the lean transformation can have an actual impact, as the SMS is assisted by the QMS, by its processes such as auditing, inspection, investigation, root cause analysis, preventive measures and statistical analysis.

What is more, it is the market's opinion, that mistakes made, are only to improve our systems, to adjust our mindsets and develop fit-for-purpose processes. Further to the above shown tables, it is important to investigate cases, where companies have not only been compromised their commercial obligations but have been convicted for committing major crimes. Companies which manage hazardous conditions and maintain SMS, face risks more elevated than other, as if their processes fail to be implemented adequately, the outcomes may be bad, and their market's position can be destroyed instantly. From operating a vessel by following procedures and manuals, to being convicted for committing major crimes, such as water pollution or accidents with fatalities, multiple factors have contributed to the accident causation. Management decisions, organizational processes, working conditions, errors and violations, regulations defiance, inadequate training, technological failures may be some of these factors, but all of them are supposedly predicted in the designation process of the SMS, hence if it fails to mitigate risks, should be classified as insufficient. Below, on Table 6. MARPOL Enforcement Cases, Source: Winston & Strawn LLP, multiple examples where insufficient or voluminous documentation, or obsolete safety management procedures, lead to crimes against MARPOL and consequently to convictions or detentions.

Table 6. MARPOL Enforcement Cases, Source: Winston & Strawn LLP

Case	Allegations	Result
1.	MV ACHILLEUS: The USCG found that the OWS of the vessel was tampered with fresh water running through the oil content meter, modification of air vent on OWS, illegal sludge drain, and OWS bypass. Also, the ship had been using a magic pipe from bilges to an overboard discharge valve for approximately 18 months.	Vessel was detained in Charleston, SC on 14 Aug 2018. On 10 May 2019, the government entered a criminal information charging the company with 2 counts: 1 APPS violation for failure to maintain an ORB, and 1 obstruction count. On 20 Jun 2019, the company entered a guilty plea, agreeing to a fine of **$1.5 million, 4 years of probation, and an Environmental Compliance Plan.**
2.	MV NICOS IV: a chemical tank ship owned by Nicos IV Special Maritime Enterprise and operated by Avin International Corp. of Panama S.A. The vessel was detained in Port Arthur on 18 Jul 2017. The CG found that the crew had failed to log cargo tank cleanings in the ORB Part II, and also failed to log tank to tank transfers of cargo. The ship incurred oil contamination of 2P, 2S, and 4S ballast tanks. An oil sheen was observed during deballasting operations in Houston on 6 and 7 Jun 2017. Captain was aware of the sheens but took no action. The vessel went to Port Arthur. Enroute, Captain attempted to	Company pled guilty to 5 counts: 1) obstruction of investigation; 2) failure to report discharge of oil; 3) negligent discharge of oil (Houston); 4) negligent discharge of oil (Houston; 5) negligent discharge of oil (Port Arthur). The plea agreement remains under seal, and the Magistrate's report does not state the agreed sentence, if any. On 3 May 2019, both companies pled guilty and were sentenced to pay **$4 million, 4 years' probation, and an ECP.**

	have the tanks cleaned of oil, but was not successful. A sheen was also observed in Port Arthur on 8 Jul. The investigation found no entries about the oil contamination, and that log entries about checking for oil were falsified.	
3.	MV NAVE CIELO: is an oil tankship owned by IOS Shipping Corp. and operated by Navimax Corporation, a subsidiary of Navios Shipmanagement Inc. CG found that the ODME had been inoperable since Jan 2016, and crew had been entering flow rate manually during that time. Failure was not noted in ORB and was not reported to Class or Flag. On boarding, crew members disclosed that vessel had discharged oily water through ODME at direction of Master and had been ordered to clean oil off of the side of the ship. Later during CG investigation, Chief Officer had direct crew members to lie to Coast Guard.	Vessel was detained in Philadelphia on 12 Dec 2017. Navimax pled guilty to one count of failure to maintain ORB and one count of obstruction. Company was sentenced to fine of **$2 million, probation for 4 years, and was required to submit a "Environmental Management Augmentation Plan"** (similar to an ECP).
4.	MV GREEN SKY: A Chemical Tankship owned by Aegeansun Gamma Inc. and operated by Aegean Shipping Management S.A. On 28 Aug 2015, the Vessel was detained by the USCG in Charleston, SC, after officers found that daily soundings for the BHT did not match the records in the ORB. Whistleblowers the reported that oilers had told of the use of a magic pipe, but report was denied by Master and company. Master Anciano pled guilty to obstruction.	Defendants were indicted on: Count 1: aiding and abetting violation of APPS (failure to maintain ORB); Count 2: falsification of records (§ 1519); Counts 3, 4, 5: Obstruction (§ 1505); Count 6: Conspiracy. ASM pled guilty, agreed to **$2 million penalty, 3 years' probation, ECP** Individual defendants went to a jury trial 30 Jan to 22 Feb 2017. CE Koutoukakis found guilty of counts 1, 2 CE Julian found guilty of counts 1, 3 2E Bounovas acquitted of all charges
5.	MV ATLANTIC OASIS: A bulk carrier owned by Salivan Shipping S.A. and operated by Nitta Kisen Kaisha Ltd. The CG found that the crew had pumped out the bilge tank directly overboard through the installed fire/bilge/ballast pump using an unapproved piping modification. In addition, they used buckets to collect sludge from the stripping line and dumped the buckets overboard.	The vessel was detained in Wilmington NC on 18 May 2017. Nitta Kisen Kaisha was charged in a criminal information on 16 Feb 2018 with an APPS count and an obstruction count. The company entered into a plea agreement, pleading guilty to both counts, and was sentenced to a fine of **$1,000,000, three years of probation, and an ECP and environmental training program.** The two Filipino whistleblowers were granted awards of $125,000 each.
6.	MV YUH FA NO 201: A fishing vessel operated by Yuh Fa Fishery (Vanuatu) Co. Ltd. Vessel was	Vessel was detained in American Samoa on 1 Jun 2016. Company pled guilty to 2 felony

	found to have OWS subject to multiple unapproved alterations and no approved method of monitoring oil content of effluent; crew was unfamiliar with proper operation and maintenance of OWS and maintenance of ORB, vessel had not had ORB kept since 2013, and CE could not record ORB operations in English, French, or Spanish. Also, CE admitted illegal discharges of oily water, and also admitted not keeping a GRB.	violations of APPS (failure to maintain ORB, failure to maintain GRB). Company was sentenced to fine of **$2.5 million (including CSP of $625,000) and 5-year probation period during which the vessels will be barred from entry into the U.S.**
7.	<u>PV CARIBBEAN PRINCESS</u>: A cruise ship operated by Princess Cruise Lines. A whistleblower alerted the UK MCA in August 2013 that the ship had been discharging oily bilge water through a bypass pipe. The MCA referred the info to the USCG. The subsequent investigation found the vessel had been making illegal discharges since 2005, and that the ORB had been routinely falsified. They found this was done regularly from 2011 to 2013. Four other vessels were alleged to have engaged in similar practices: GOLDEN PRINCESS, CORAL PRINCESS, GRAND PRINCESS, and STAR PRINCESS. A cause was overflowing of grey water tanks into the bilges – the crew pumped the water back to the grey water tanks and then overboard. Problem was recurring for years, but the company did not create policies or have training on how to deal with it.	Princess entered into a plea agreement, pleading guilty to: Count 1: Conspiracy Counts 2-5: APPS violations Counts 6-7: Obstruction Princess agreed to a total monetary penalty of **$40 million**, allocated as $27 million to Count 1, $3 million (total) to counts 2-7, and **$10 million for Community Service Payment**. The agreement also includes **a 5-year probation period and ECP applicable to Princess and Carnival Corp. and Carnival Plc.** Whistleblower was awarded $1 million. Company was sentenced IAW the plea agreement on 19 Apr 2017.
8.	<u>MV MINERVA MARINA</u>: A Greek flag tank vessel owned by Minerva Marine Inc., and operated by Rourke Services Ltd. During testing of the OWS, the sample line to the OCM was observed to be closed. The 2E stated that he used a valve to control the sample, to allow discharges to proceed	Vessel was detained in Philadelphia on 4 Nov 2016.
9.	<u>MT OCEAN PRINCESS</u>: is a tank vessel operated by Ionian Shipping & Trading Corp. and owned by Lily Shipping Ltd. The CG found that the vessel operated in the U.S. ECA with fuel with a sulfur content of between 0.3 % to 0.318% per bunker delivery notes. It was found that vessel used non-low sulfur fuel, created 19 false bunker delivery notes, and falsified the ORB re bunkering. They also found	Vessel was detained in St. Croix on 11 Jul 2018. On 10 Apr 2019, the Government charged the Defendants—Ionian S&T = technical manager; Lily Shipping Ltd = owner, and Ionian M = commercial manager. Charges included was charged with Cnt 1: APPS, operating in the NA ECA with fuel exceeding 0.1% sulfur.

	that crew members were told to lie to the CG by Chief Officer Rey Espulgar. Dyachuk stated in interviews that he was told by other crew members that the Chief Officer told them to lie.	Cnt. 2: APPS, failure to accurately maintain ORB. Cnt. 3: APPS, failure to accurately maintain Bunker Delivery Notes Cnt. 4: Obstruction of investigation, telling crew to lie to USCG On 23 Apr 2019, Ionian entered into a guilty plea to Counts 1-4 for a fine of **$1,500,000, a 4-year probation, and an ECP**. Lily entered into a plea to Counts 1-4 for a fine of **$1,500,000, 4 years of probation, and involvement in an ECP (as owner!)**

Where:

- USCG: United States Coast Guard
- OWS: Oily Water Separator
- OCM: Oil Content Meter
- GRB: Garbage Record Book
- ORB: Oil Record Book
- ECP: Environmental Compliance Plan
- ECA: Emissions Control Area
- CSP: Community Service Payment
- APPS: Act to Prevent Pollution from Ships
- UK MCA: Maritime and Coastguard Agency, UK
- ODME: Oil Discharge Monitoring Equipment

- **Case 1**: In this case, it is apparent that the company was completely unaware of the situation onboard, which would indicate a complete SMS's implementation failure and significantly reduced training and familiarization on the environmental matters. If the company was aware and the actions were prescribed by the office, then a total lack of safety and environmental culture in the top management, is observed.

- **Case 2**: In this case, a failure of the vessel's systems was not properly reported to the office personnel and was confined within the crew. Unluckily, the Captain was either not aware of the environmental damage that would cause, which would translate on insufficient training, or he was aware and though that we would be caught, which in that case, a total failure of the company's culture to educate adequately its crew, is observed.

- **Case 3**: In this case, the incident has been reported by the crew, directly to the authorities, which indicates a mistaken culture of safety in the company, as the crew should have reported the incidents in the office personnel, in order to mitigate effects or take actions.

The course of actions, indicates that the crew was well aware of the problem and failed to report it. Open reporting, within the company, is a matter of culture and an effective SMS implementation should endorse such actions.

- **Case 4**: In this case, crew had been operating completely illegal, which indicates insufficient training and familiarization with the ISM Code, as well as the basic environmental awareness. The use of magic pipe indicates an ‘organized crime’ as such installation, usually will not pass from an internal audit.

- **Case 5**: In this case, practices that used to take place before 2000 are observed, which indicates a total lack of education and training with the environmental matters, which further indicates a lack of culture within the company. Such actions also indicate that the existence of the company’s SMS is for compliance reasons only and not as an instrument to avoid high risk conditions.

- **Case 6**: In this case, the vessel’s crew had a total lack of education on these matters. The fact that the ORB had not been completed for almost 3 years also indicates that the company had no concern about the vessel’s operating condition, no audits and therefore insufficient sources/funds spent in safety management system.

- **Case 7**: This is a self-explanatory case, which shows that even huge companies with an established name within the market can have such incidents, where not-well-trained crew and multiple failures of various safety measures can be surpassed. The SMS should be maintained as a living organism, on a daily basis.

- **Case 8**: Same as case 1.

- **Case 9**: In this case, a bypass of multiple SMS’s procedures is observed, which translates either to a very uneducated crew or not fit-for-purpose system used.

All the above examples used, serve to make clear that the performance of the company’s Safety Management System, is not to be left at its luck, but should be closely monitored, as there is an apparent connection between the system’s performance and the compliance. Through the years, multiple events have taken place, either major environmental violations or fatal accidents. All these events should be treated as lessons-learned from the shipping community, in order to optimize their objectives and have clear vision of their internal processes. The lean transformation of the SMS is mandatory, as during the evolution and the development of proactiveness mentality, documentation increases rapidly in terms of volume, thus, a documentation optimization process is also required, where automation cannot be effective.

4.2 Specific Implementation

Recently, increasing competition and charterers' strong performance requirements, as well as a bombard of regulations, have prompted shipping companies of the industry, to review their internal processes, aiming to achieve more adaptive and proactive quality management systems. Minimization of the time lost for internal procedures and more focus on the optimization of vessels' performance to minimize their operating costs, constitute parts of a larger effort towards the increase of the profits and the company's ability to expand along with personnel's development.

The technical implementation section of subject thesis has been inspired by numerous and continuous observations of a company's QMS & SMS are they were applied by different departments and people within the company Tsakos Columbia Shipmanagement "TCM" S.A. Specifically, the methodology presented above, was formulated gradually during multiple conversations and interviews with various Technical and Marine Superintendents, along with the Energy & Environmental Manager, who provided enough evidence and sources, aiming to achieve the adoption of the digital era in the company's quality and safety management system.

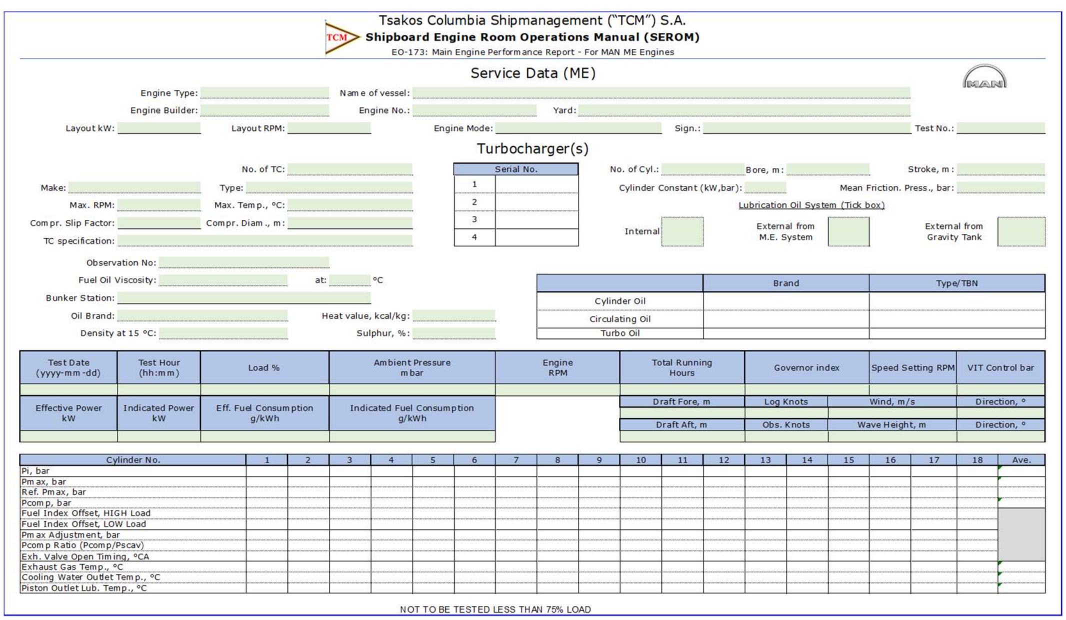
The scope of the specific implementation, is an exploration of Lean Transformation methodology's applicability on a specific process of the company, evaluating the level of transformation that can be achieved with **no additional funds and sources used**, using only the existing ones, just by 'reprogramming' and 'rearranging' the system's structure and operational procedures. As it was noticed that the process of data collection for the completion of the ISM Forms by the vessels and their submission to the company, has a significant potential for improvement, the specific process was chosen to be investigated. The methodology was applied as per Case 1, on a large company's QMS, which can provide enough evidence for its accuracy and effectiveness, due to the complexity and the volume of the processes.

In particular, the company's manual for the Engine Room, is called Ship's Engine Room Onboard Manual (SEROM) and consists of 12 Procedures, 6 Posters and 24 forms. The main goal was set to explore the possibility to automate the procedure for completion of at least one of the below forms, as far as possible. First priority is to define a form which can be automatically filled using only the existing systems onboard. The forms are presented below:

- Changing Over the ER Watch Checklist
- Navigation in Ice Checklist
- Engine Room Preparation for Departure Checklist
- Engine Room Preparation for Arrival Checklist
- Record of Ozone Depleting Substances
- Lubricants and Grease Inventory
- Gases Bottle Inventory
- Steering Gear Daily Routine Inspection
- Low Load Operation – Inspection Report
- UMS Duty Engineer's Checklist

- Oil Water Separator Report
- Master List of Seals
- Deck and Engine Flexible Hoses
- Sewage Discharge Log
- Chemical Dosing Log (STP)
- Sewage Treatment Plant Maintenance
- Supplement to the Chief Engineer's Change Over Command Protocol Form (Special Tools List)
- ME Performance Report – Non-MAN Engines
- ME Performance Report – For MAN MC Engines
- ME Performance Report – For MAN ME Engines
- ME Performance Report – For MAN ME-B Engines
- ME Performance Report – For MAN ME-C Engines
- Diesel Generator Performance Report
- Fresh Water Generator Performance Report

Due to the nature of their content (mainly checklists and inventories), the majority of subject forms require to be filled manually or would require additional sources such as a software to keep track of the vessel's inventories. In order to avoid any additional costs and installations of sensors, and after thorough examination of the sensors available on board, it was decided that Lean Transformation methodology can be applicable to a significant extend on the Main Engine Performance Report forms. In order to have a more detailed and high-accuracy data of completion, the MAN ME Engine was chosen, as the majority of its operation is controlled electronically using sensors and gauges. The form is shown in Figure 19. Main Engine Performance Report - For MAN ME Engines, page 1/2 and Figure 20. Main Engine Performance Report - For MAN ME Engines, page 2/2 (they can also be found in Annex)


Tsakos Columbia Shipmanagement ("TCM") S.A.
Shipboard Engine Room Operations Manual (SEROM)
EO-173: Main Engine Performance Report - For MAN ME Engines

Service Data (ME)

Engine Type: Name of vessel:
Engine Builder: Engine No.: Yard:
Layout kW: Layout RPM: Engine Mode: Sign.: Test No.:

Turbocharger(s)

No. of TC:
Make: Type:
Max. RPM: Max. Temp., °C:
Compr. Slip Factor: Compr. Diam., m:
TC specification:

Serial No.	
1	
2	
3	
4	

No. of Cyl.: Bore, m: Stroke, m:
Cylinder Constant (kW,bar): Mean Friction. Press., bar:
Lubrication Oil System (Tick box)
Internal External from M.E. System External from Gravity Tank

Observation No:
Fuel Oil Viscosity: at: °C
Bunker Station:
Oil Brand: Heat value, kcal/kg:
Density at 15 °C: Sulphur, %:

	Brand	Type/TBN
Cylinder Oil		
Circulating Oil		
Turbo Oil		

Test Date (yyyy-mm-dd)	Test Hour (hh:mm)	Load %	Ambient Pressure mbar	Engine RPM	Total Running Hours	Governor index	Speed Setting RPM	VIT Control bar

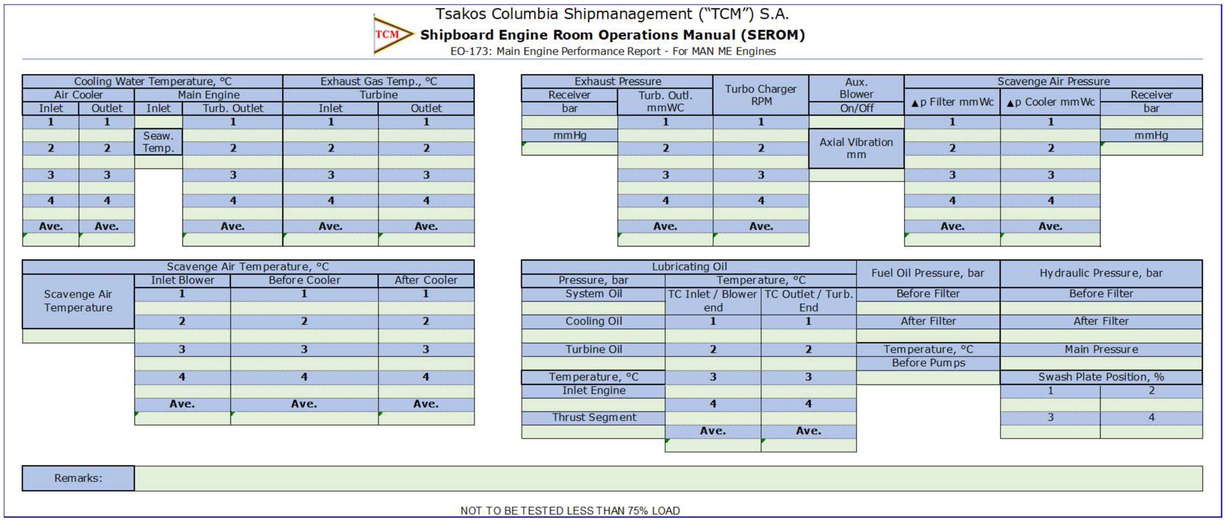
Effective Power kW	Indicated Power kW	Eff. Fuel Consumption g/kWh	Indicated Fuel Consumption g/kWh

Draft Fore, m	Log Knots	Wind, m/s	Direction, °
Draft Aft, m	Obs. Knots	Wave Height, m	Direction, °

Cylinder No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Ave.
Pi, bar																			
Pmax, bar																			
Ref. Pmax, bar																			
Pcomp, bar																			
Fuel Index Offset, HIGH Load																			
Fuel Index Offset, LOW Load																			
Pmax Adjustment, bar																			
Pcomp Ratio (Pcomp/Pscav)																			
Exh. Valve Open Timing, °CA																			
Exhaust Gas Temp., °C																			
Cooling Water Outlet Temp., °C																			
Piston Outlet Lub. Temp., °C																			

NOT TO BE TESTED LESS THAN 75% LOAD

Figure 19. Main Engine Performance Report - For MAN ME Engines, page 1/2


Tsakos Columbia Shipmanagement ("TCM") S.A.
Shipboard Engine Room Operations Manual (SEROM)
EO-173: Main Engine Performance Report - For MAN ME Engines

Cooling Water Temperature, °C — Air Cooler: Inlet, Outlet; Main Engine: Inlet, Turb. Outlet; Seaw. Temp.
Exhaust Gas Temp., °C — Turbine: Inlet, Outlet
Exhaust Pressure — Receiver bar, mmHg; Turb. Outl. mmWC
Turbo Charger RPM
Aux. Blower On/Off
Axial Vibration mm
Scavenge Air Pressure — ▲p Filter mmWc; ▲p Cooler mmWc; Receiver bar, mmHg
Scavenge Air Temperature, °C — Scavenge Air Temperature; Inlet Blower; Before Cooler; After Cooler
Lubricating Oil — Pressure, bar: System Oil, Cooling Oil, Turbine Oil; Temperature, °C: TC Inlet / Blower end, TC Outlet / Turb. End; Temperature, °C: Inlet Engine, Thrust Segment
Fuel Oil Pressure, bar — Before Filter, After Filter, Temperature, °C Before Pumps
Hydraulic Pressure, bar — Before Filter, After Filter, Main Pressure, Swash Plate Position, %
1 2 3 4 Ave.
Remarks:
NOT TO BE TESTED LESS THAN 75% LOAD

Figure 20. Main Engine Performance Report - For MAN ME Engines, page 2/2

4.3 Existing Process

Main Engine Performance Report is an ISM form and the vessel's crew is required to submit it on a weekly basis. At the same time, various parameters have to be in place in order to proceed with the reporting, such as a Load of 75% and above. Chief engineer and other ER Officers must collect all the required data manually from all around the Engine Room, as in some cases the values can be taken by indicators in the Engine Control Room and in other and more frequent cases, values have to be taken by the sensors and gauge which are installed on each machinery and require the personnel's physical presence (e.g. Total Running Hours). Having collected all the data, the Chief Engineer must fill the form, sign it and send it by mail to the office, for the Technical Superintendent in charge to proceed with its evaluation.

All this time-consuming process is taking place each time personnel from the office asks from each and every one of the 81 vessels for the Main Engine performance test. It should be noted also, that during the data collection, the main engine is running and the values are constantly changing, which means that by the time the responsible officer will collect a value from a machinery, the previous value from another will have already changed, as a result, the report is not a 'photographic' representation of parameters due to their fluctuation. Combined with the data collection made by hand, the probability for human error reporting increases significantly.

In addition, with the existing system, the Technical Superintendent is required to keep a database of the forms, in order to be able to trace back engine's performance in time, but in a discrete form, depending on the timely and effectiveness of the form's submission. Adequate performance monitoring, appears to be an imperative tool of the office personnel against increased fuel consumption, engine parts wear monitoring etc. Therefore, a competent and efficient process for data keeping and evaluation is compulsory.

At the same time, since 2016, the company has introduced an in-house developed software as an enterprise resource planning (ERP), called 'Ultima'. Ultima is an online platform which integrates the management of main business processes, in which an employee is able to monitor all vessels' locations and noon reports, crews onboard and ashore, performance indicators (for vessels fitted with live measurement tools), spares and open requisitions etc. One of the main benefits of the in-house software is the ability to customize and solve with ease bureaucratic procedures and legal implications.

Currently, the only connection between Ultima and the vessels is the noon reporting procedure, which is a mandatory process dictated by the ISM and provides the vessel's position and other relevant standardized data to assess the performance of the ship based on its speed and environmental forces including weather conditions. But all the data submitted in the noon reports is mainly human input, which increases the error probability by default, again.

4.4 Suggested Process

All modern vessels are equipped with an Alarm Monitoring System (AMS), which incorporates all available alarms' and sensors' outputs at any given time. In particular, all outputs are connected to Distributed Processing Units (DPU), a device which gather different signals, converts and sends them to the AMS enabling users to have continuous access to primary vessel data, both onboard and from ashore.

The concept is to develop a process from which the performance form, will be able to access the required data that is available on the AMS, and be filled automatically, allowing the Technical Superintendents to have a performance report upon request, at any given time, without overloading crew with data collection procedures, especially when this data is already available in electronic format. The benefit of this system, apart from time conservation and increased data accuracy (depending always on sensors and gauges reliability), is that data can have a continuous flow, with no interruptions and the representation of the engine's parameters will be totally accurate and 'photographic'.

Explaining, for example, when engine's power (kW) is recorded by the crew at time t_1, until the officer collects the respective shaft revolutions (RPM) at time t_2, the power may have already changed, within the t_2-t_1 time space, decreasing the overall accuracy of the evaluation. The suggested method will record all available values at the same time, creating tables for any time interval the user has selected. Later, these tables will be transmitted automatically, by mail on Ultima, which will store the data. On the second stage, data which is already stored in company's servers, will be able to fill the respective form (in our case Main Engine Performance Report - For MAN ME Engines) for any timeframe requested by the Tech. Superintendent.

A schematic diagram of the suggested process is shown in Figure 21. Suggested System Overview. Summarizing, the flow of information will be the below:

- Sensors and Gauges collect data
- Data is transferred to DPU, for processing
- Processed Data is transferred to AMS for centralization
- Data is saved to the vessel's server (limited capacity)
- Data is transmitted via Satellite Communications (VSAT etc.) to the office

- Data is stored in the office's servers (full historical data)
- Data is uploaded to the company's ERP, Ultima
- Data is 'translated' to develop reports and diagnostics.
- Performance Report form is ready upon request, at any given moment

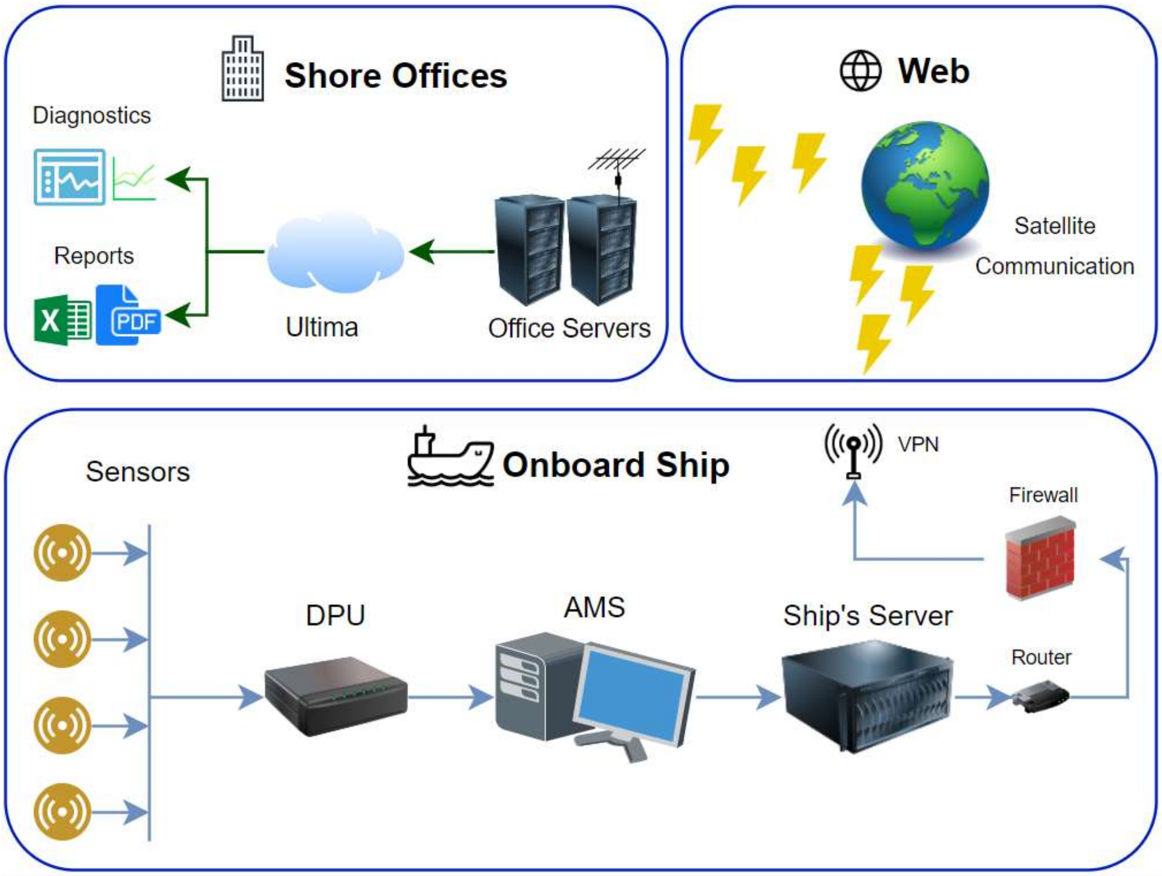


Figure 21. Suggested System Overview

4.5 Sensors & Gauges

At this point, having showed the overview of the suggested process, it is needful to present the common equipment that can be used to measure the system's input, or else said, the sensors and gauges. This equipment is available onboard the majority of the modern vessels and its proper exploitation is almost mandatory nowadays. Before the analysis of the basic operating principles and functions of the monitoring equipment, it is important to have in mind the quantity and nature of the systems that is required by the law or is desired by the ship-managers to be close monitored. Below is a brief list of the majority of those systems:

- Main Engine Monitoring System
- Auxiliary Engines & Generators Monitoring System
- Electric Monitoring System
- Instrument Monitoring System

- Power Management System
- Boiler Monitoring System
- Purifier Monitoring System
- General & Fire Alarm System
- Engine Room Auxiliary Machinery Monitoring System
- Pump Control & Monitoring System (incl. Ballast Pumps)
- Thruster Control & Monitoring System (Bow & Stern)
- Cargo Auxiliary Machinery Monitoring System
- Automatic Unloading System (AUS)
- Bilge Monitoring System
- Tank Level & Draft Gauge System
- Ballast Valve Remote Control & Monitoring System
- Cargo Valve Remote Control & Monitoring System
- HFO Filling Valve Remote Control & Monitoring System (Heavy Fuel)
- DO Filling Valve Remote Control & Monitoring System (Diesel Oil)
- LO Filling Valve Remote Control & Monitoring System (Lub. Oil)
- High Pressure Unit Monitoring System (System Oil)

Amongst the above systems, the sensors and gauges used are all the same, which means that only a few types of sensors are enough to get the proper measurements, given that they are arranged properly. The most important types of sensors are presented below, along with their operating principles.

4.5.1 Pressure Sensor

Pressure sensors utilize a sensing element of constant area which responds to mechanical deformation when any force is applied to this area by any fluid pressure. That mechanical deformation causes a deflection of a diaphragm inside the pressure sensor, which is measure and converted into an electrical output, usually but not always, linear.

1. **Gauge Pressure** sensor measures a process's pressure in reference to the ambient atmospheric pressure, which is an average of 1013.25 mbar at sea level. An example of this sensor is shown in Figure 22.

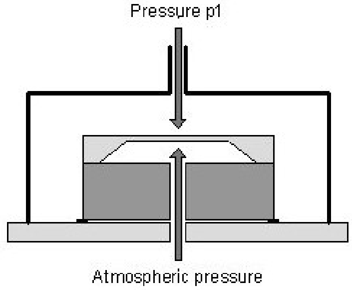


Figure 22. Gauge Pressure Sensor (Source: www.first-sensor.com)

2. **Absolute Pressure** sensor measures a process's pressure in reference to the vacuum of free space, aiming to exclude the variations in atmospheric pressure. An example of this sensor is shown in Figure 23.

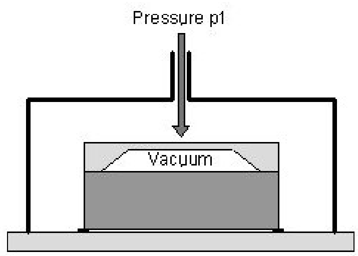


Figure 23. Absolute Pressure Sensor (Source: www.first-sensor.com)

3. **Differential Pressure** sensor measures the difference between any two process pressures, offering two separate pressure ports. Unlike gauge or absolute pressure transmitters have no reference pressure. An example of this sensor is shown in Figure 24.

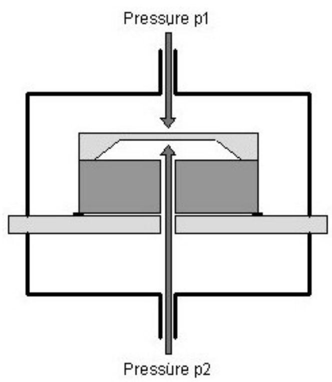


Figure 24. Differential Pressure Sensor (Source: www.first-sensor.com)

4.5.2 Temperature Sensor

Thera are many types of temperature sensors, as temperature is the most commonly measured physical parameter. Each type has a different operating principle , which provides accuracy in different temperature ranges, depending on the application. The most important thing to mention about their operating principles is that all types of sensors, measure the temperature by measuring the change of physical characteristic, such as conductivity.

1. **Negative Temperature Coefficient (NTC)** sensor is a thermally sensitive resistor which demonstrates a significant, predictable and precise change in its resistance depending on the variations of the temperature. The common operating range of such a sensor is -50 to 150~200 ^{o}C. It is preferred for lower temperatures due to its very fast response with high accuracy per ^{o}C. The relation of resistance and temperature of an NTC sensor is shown in Figure 25.

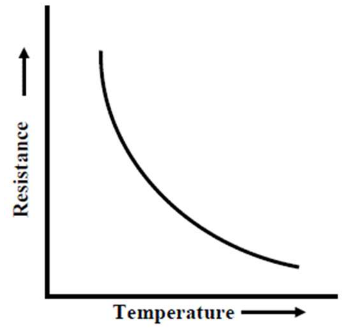


Figure 25. Resistance Vs Temperature of an NTC sensor

2. **Resistance Temperature Detector (RTD)** sensor utilizes the correlation between the temperature and the resistance of the RTD element in order to provide accurate measurements. Usually the RTD is a thin film or a wire wrapped around a ceramic or glass core, the wire can be from nickel, copper or platinum. The common operating range of such a sensor can be -200 to 600 ^{o}C, but while they provide high accuracy, they are the most expensive temperature sensors. An example of the different wire materials' correlation with temperature is shown in Figure 26.

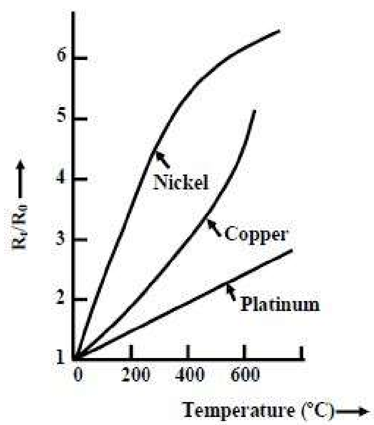


Figure 26. Different Wire Materials Vs Temperature Relation

3. **Thermocouple** sensor consists of two metal wires of different material connected at two points and the varying electrical current between these two points reflects a direct relation with the temperature. The electric output of the sensor is not linear; therefore, a conversion is needed. They are not famous for their accuracy (0.5 to 5 ^{o}C), but their wide temperature range is mentionable, which is from -200 to 1750 ^{o}C. A typical operating principle of a thermocouple sensor is shown in Figure 27.

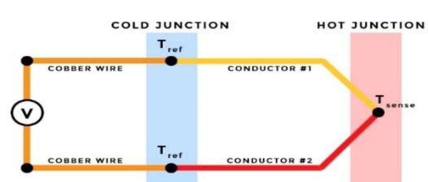


Figure 27. Thermocouple Sensor Operating Principle

4.5.3 Level Sensor

The level sensors are mainly six (6) different types, Capacitance, Hydrostatic, Magnetic, Radar Fill, Ultrasonic and Guided Microwaves.

1. **Capacitance Level** sensor utilizes a liquid stored in a dielectric medium between two or more electrode, therefore, the energy capacity of the circuit increases along with the liquid contained in the tank. An example of the application of such sensor is shown in Figure 28.

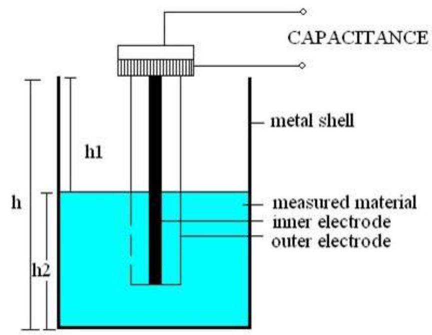


Figure 28. Capacitance Level Sensor

2. **Hydrostatic Level** sensor uses a pressure sensor to determine the liquid content of the tank by measuring the pressure of the fluid at the bottom of the tank. An application of such sensor is shown in Figure 29.

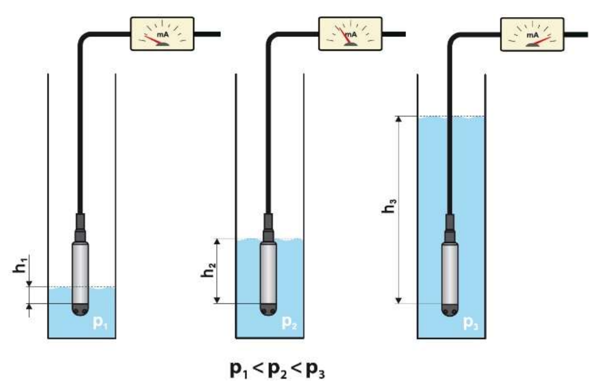


Figure 29. Hydrostatic Level Sensor

3. **Magnetic Level** sensor uses a magnetic material suspended in a buoyant float in a narrow auxiliary liquid column, to restrict various movement of the floating object. The operating principle of this sensor is shown in Figure 30.

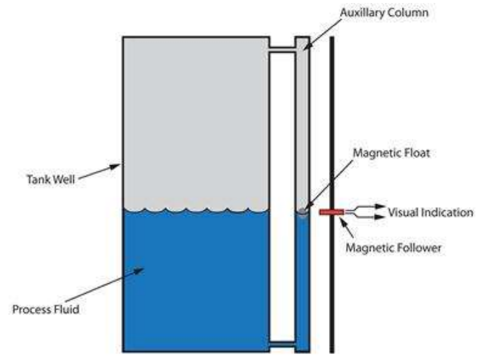


Figure 30. Magnetic Level Sensor

4. **Radar Fill Level** sensor use the principle of a two-wave emissions radar, mounted on top of the tank, by sending a signal into the liquid and receiving its reflection and then measure the tank filling by measuring the time taken by the transmitted signal to return. An example of such sensor is shown in Figure 31.

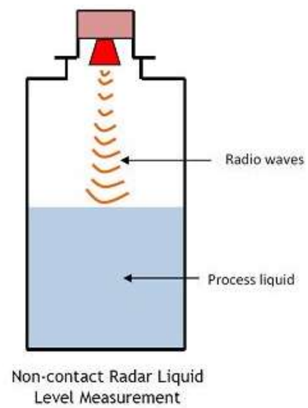


Figure 31. Radar Fill Level Sensor

5. **Ultrasonic Level** sensor uses the same principles as the Radar Fill Level sensor, except that it calculates the liquid fill depending on the time difference between the transmitted and reflected/received signal. An example of such sensor is shown in Figure 32.

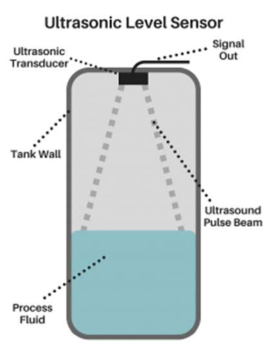


Figure 32. Ultrasonic Level Sensor

6. **Guided Microwave Level** sensor uses a sensor cable or rod as a medium to send a microwave pulse and measure the time it takes for the signal to hit the surface of the liquid and travel back, to determine the liquid fill of the tank. An example of such sensor is shown in Figure 33.

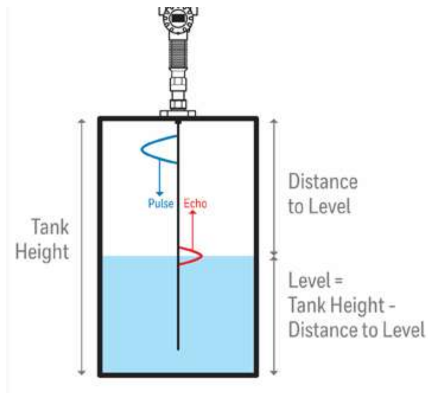


Figure 33. Guided Microwave Level Sensor

4.5.4 Oil Mist Detector (OMD)

The purpose of this sensor is to detect the presence of oil mist in the vapors of the crankcase, which translates to a significant reduction of the flash point of the system oil and an increasing threat for explosion, respectively. The crankcase of each cylinder is connected to the OMD, which continuously checks the air sample from each cylinder. The operating principle of the sensor is shown in Figure 34. Two identical beams of light are reflected in two chambers, one with reference atmosphere and one with the vapors of the crankcase. When the oil mist is increased, the light will be obscured before reaching the photocell which will cause the alarm to go off.

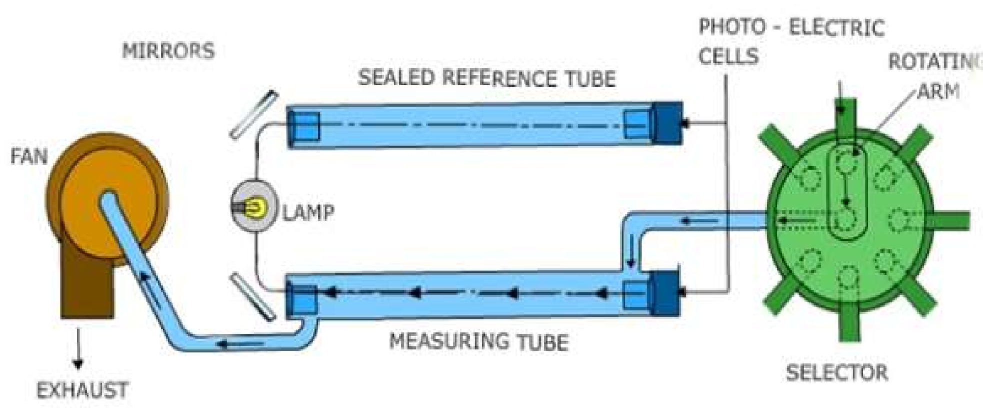


Figure 34. Oil Mist Detector Operating Principles (http://marinegyaan.com)

4.5.5 Flowmeter Principles & Applications

In marine application the flowmeters used have to be robust; to sense fuels with low viscosity and temperatures above 100 ^{o}C and to be able to register potential backflows of the liquids, due to pressure pulses caused by the fuel injection pumps. The flowmeters are two main types, the Mass and the Volume flowmeter.

1. **Mass Flowmeter** applies the Coriolis measuring principle. The liquid/fuel flows through a tube, which is excited to vibrate at resonance frequency, as shown in Figure 35, and the vibration pattern of the tube is detected with two distance probes at both ends of the tube. If the flow is zero, the vibration at both ends is in phase, but if there is a flow, the vibration phase is shifted. The frequency of the tube oscillation changes along with the density of the passing fluid.

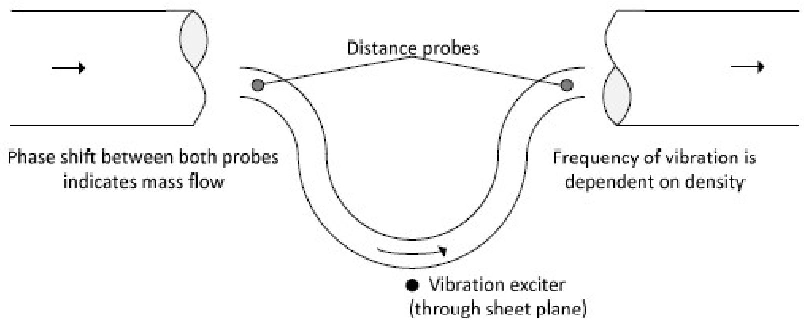


Figure 35. Mass Flowmeter Operating Principle (Source: DNV-GL)

2. **Volume Flowmeter** consists of a chamber with defined volume which is passed by the fluid which rotates a rotor or a screw spindle inside this chamber. The rotational speed is proportional to the passing volume of the fluid per unit of time. The circulation of the members takes into consideration potential return flows (from injection pumps) and the temperature of the fluid is used for the density correction of the flow. The operating principles of the volume flowmeter are shown in Figure 36.

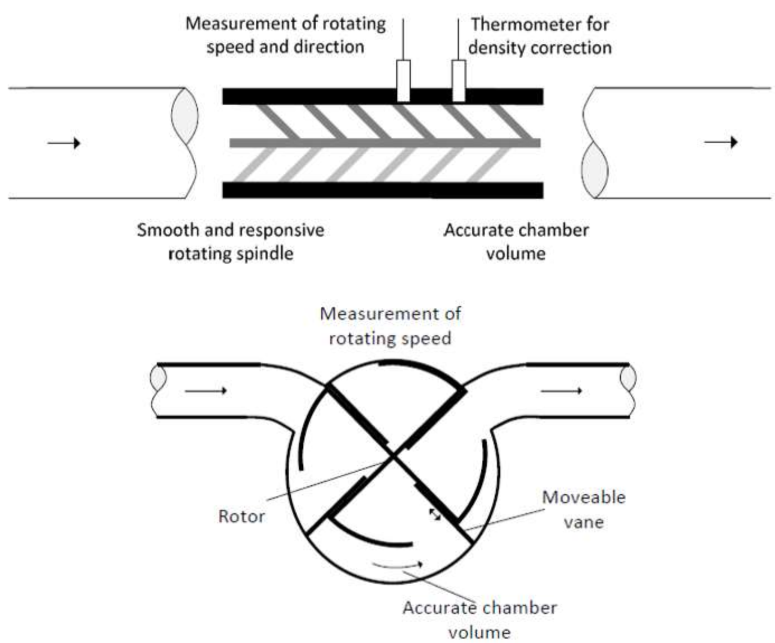


Figure 36. Volume Flowmeter Operating Principle (Source: DNV-GL)

The flowmeters are a very important tool for the monitoring of the vessel's performance and as a result they must be efficient and accurate. Depending on the application and the desired level of accuracy, there are multiple arrangement in the Fuel Service Line that can be applied and the most common of them are presented below:

1. **Single Line Measurement** is used when the propulsion engine has its own fuel supply system. Another independent fuel supply system is installed for the auxiliary engines. This system does not allow real time measurements. An exemplary arrangement is shown in Figure 37.

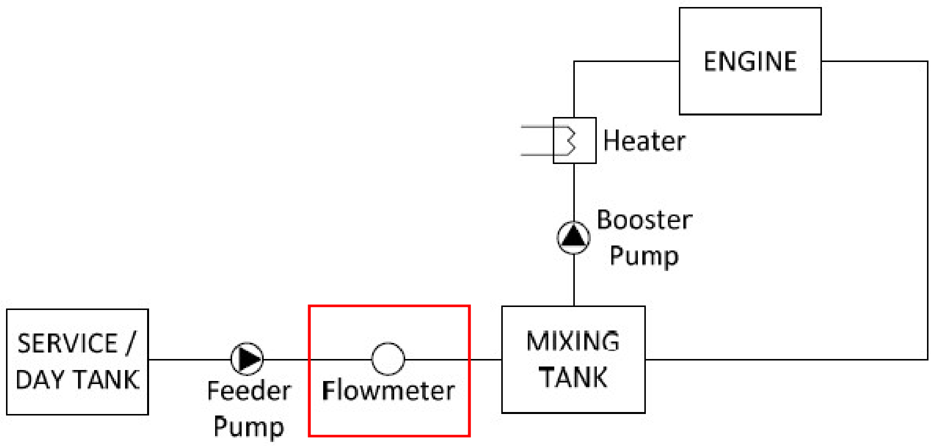


Figure 37. Single Line Measurement

2. **Differential Measurement**, is employed when the service tank is not for daily usage only and the difference between the flow in the supply and the return line, is required. This system allows real time measurements with current values of consumption. An exemplary arrangement is shown in Figure 38.

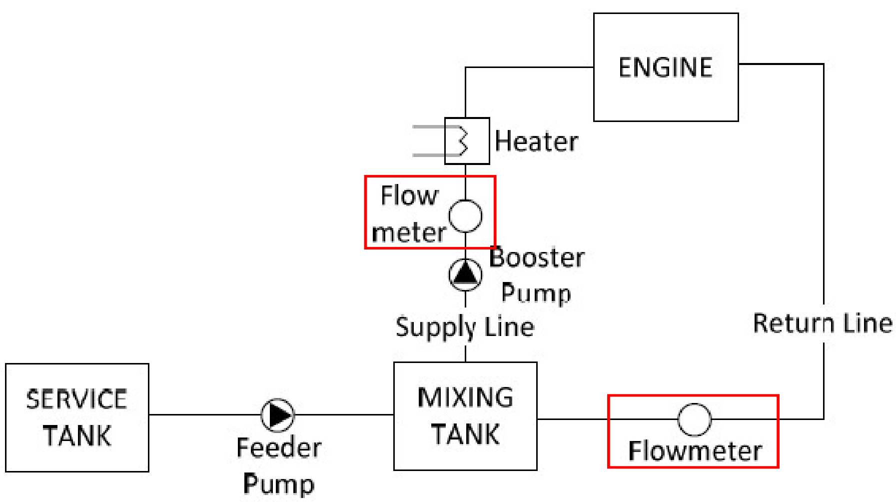


Figure 38. Differential Measurement System

3. **Mono or Uni Fuel System** is used when the M/E and the A/Es are supplied by the same fuel system. An exemplary arrangement is shown in Figure 39Figure 38.

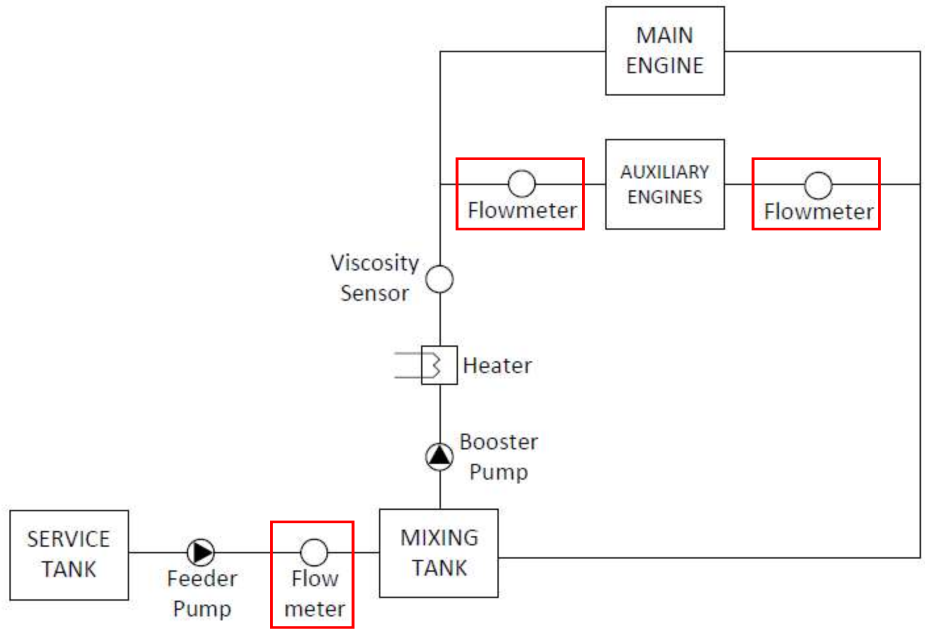


Figure 39. Mono or Uni Fuel System

4. **Multi Engine Arrangement System** provides the highest accuracy of all arrangement but with a very increased cost, as the flowmeters employed are up to 8. It allows real time performance comparison of all A/Es and consumption of M/E. An exemplary arrangement is shown in Figure 40.

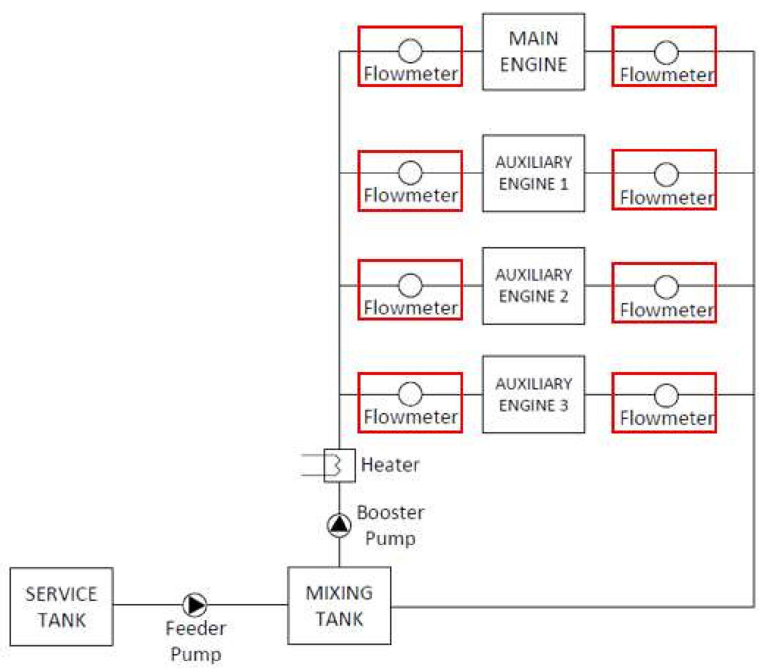


Figure 40. Multi Engine Arrangement System

4.5.6 Shaft Power Meter

One of the most important parameters to measure when one is interested in the performance monitoring of a vessel is the Delivered Power, or the power that is transmitted to the propeller. The delivered power can be calculated from the shaft power, multiplied by the shaft efficiency, which is usually a factor such as 0.99. The shaft power is calculated through the Torque, M_t, and the shaft speed, n, as shown below:

$$P = 2\,\pi\,\frac{n}{60}\,M_t$$

Therefore, the parameter under investigation, becomes the torque of the shaft. There are 3 methods currently for measuring the torque, but the first two measure the torque indirectly by measuring its impact on the shaft. The first one is to measure the twist angle of the shaft, the second to measure the surface strain and the third is to measure the torque by measuring its impact on the magnetic fields.

1. **Twist Angle**, uses the following equation:

$$M_t = G\,\frac{\pi}{16}D^4\,\frac{\varphi}{L}$$

   Where G is the G-modulus and other parameters are shown in Figure 41.

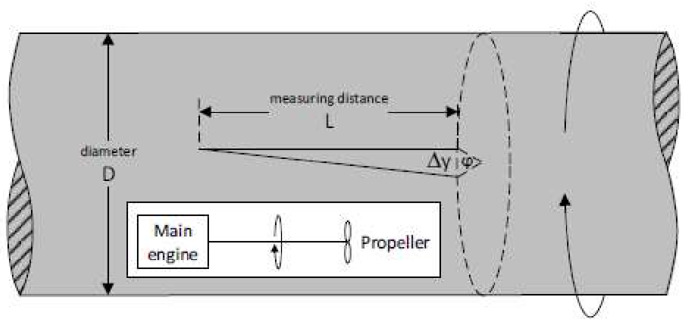


Figure 41. Twist Angle Method

The equipment used to measure the angle ϕ is the following:

- *Phase Difference between two disks*, as shown in

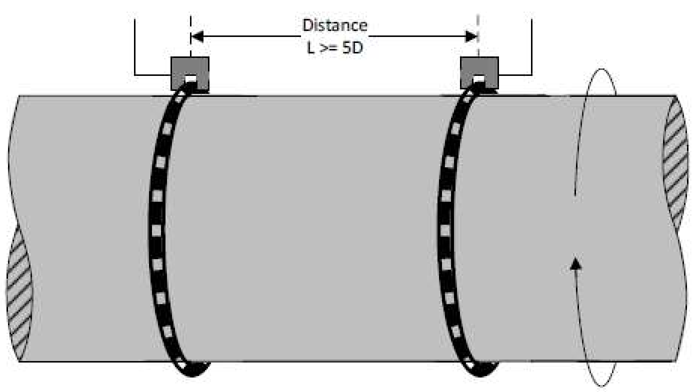


Figure 42. Phase Difference Between Two Disks

- *Displacement between two rings*, using the following equation:

$$\varphi = \frac{2\,\Delta y}{D}$$

Using a fork and two sensors, as shown in Figure 43.

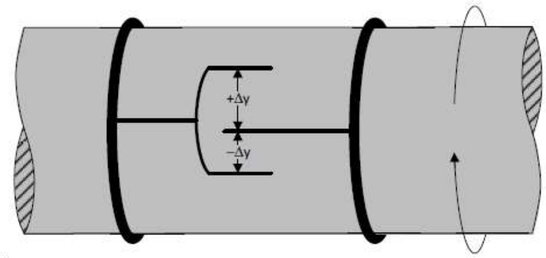


Figure 43. Displacement Between Two Rings

Or using an optical system, as shown in Figure 44.

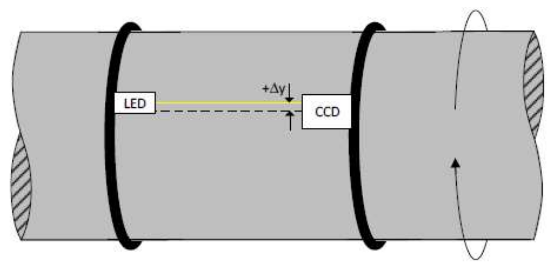


Figure 44. Displacement Measured via Optical Distance Sensor

2. **Surface Strain**, uses the principle that the strain ε_{45} at the surface of the shaft in 45° direction is proportional to the torque, as in the following equation:

$$M_t = 2\,G\,\frac{\pi}{16}D^3\,\varepsilon_{45}$$

Where G is the G-modulus and D is the shaft diameter. A common arrangement is shown in Figure 45.

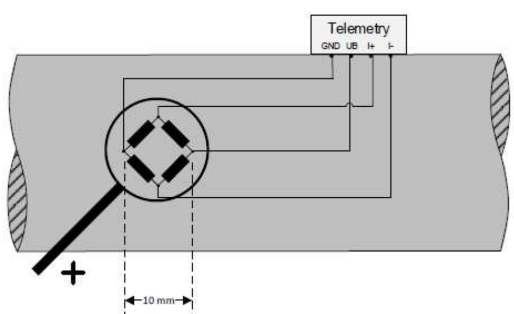


Figure 45. Surface Strain Gauge

3. **Magnetostrictive Sensors** use the principle that when shaft is exposed by torque, the permeability of the ferromagnetic steel shaft will change. It uses an arrangement of an excitation coil which generates a magnetic field and a sensing coil that measures the field,

to detect change of permeability. The effect provides non-linear changes; therefore, a sensor calibration is needed, accordingly. A common arrangement is shown in Figure 46.

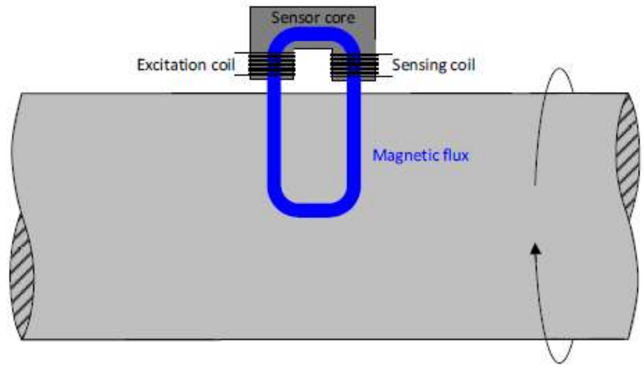


Figure 46. Magnetorestrictive Torque Sensor

All the above arrangements have their pros and cons, depending on the application and the user's desires. It is important to mention though that the error of G-modulus is a constant problem amongst all methods of measurement and should be take into account, accordingly.

4.6 Lean Transformation

At this section, the methodology developed is used to evaluate the appropriateness of the suggested process and its applicability to the company's ISM system.

4.6.1 Stage 1: Customer – Added Value

The scope of this process is the office personnel and the technical superintendent in charge to have a clear view and understanding of the vessel's main engine performance, with all relevant parameters and be able to identify any potential malfunctions or reduced efficiency. What is aimed to be achieved is to reduce the procedures needed for the main engine's data to reach the office, while the real value of the process and the desired output is the data accuracy, the availability of the report upon request, the avoidance of mistakes, error reporting, predictive maintenance, hidden values and failures, as well as a holistic view of the engine at any given moment.

Ideally, this process would not exist at all, as the office would have immediate access to all vessel's parameters and operational conditions, with a continuous flow of information, directly on company's servers. The limitations that may be faced during the implementation of any innovative or lean approach of the process, originate from the potential lack of sensors and gauges at all required locations and machineries (e.g. currently, the scavenge air pressure is measured with a built-in toolkit, made by the engine manufactures and there is no direct output of the measurement to the DPU and AMS of the Inductive Position Measuring System (PMI)). Currently, the process appears to not be lean at all, as it seems to be highly bureaucratic and complex, but still, it is observed that it is common practice for the industry.

4.6.2 Stage 2: Process Waste Identification

This process is an indispensable part of the company's SMS, as it works as a diagnostic tool for the Tech. Sup. to define the engine's state and react accordingly, even for the crew's evaluation.

The main waste, within the process, is introduced by the manual method of its completion, as the Ch. Eng. responsible, shall be able to collect all the requested (by the form) values, from the respective machineries. At the same time, various constraints should be in effect in order to have a high-quality result (e.g. Engine Load >75%), which at the moment they cannot be verified by an external observer, but only by the Ch. Eng. words and calculations.

In addition, since the time intervals between performance reporting are quite long, the vessel's owner is not in a position to observe the variance of the vessel's machineries' performance as well as the adequacy of the maintenance. In a more detailed view, the reporting processes, do not only contain a significant quantity of waste, but they also trigger and promote a wider problem, that of inadequate and reactive maintenance only, as they limit they monitoring process to photographic representations of the engine, instead of logs, trends and reports, which stands against the standards of our era, which prescribe proactive maintenance (e.g. Bearing Wear Monitoring System) and cost-benefit analysis of the spares quality etc.

Next, having collected all the data, the Ch. Eng. is required to fill the form, in the excel, then to print it, sign it, scan it and send it to the office in a non-editable .pdf document, from which the information contained can only be obtained with the eyes. Concluding, reviewing the existing process, it is apparent that the room for improvement is huge and the technology is not used effectively, at all. Especially when the vessels are equipped with so advanced technologies.

4.6.3 Stage 3: Procedures & Added Value Mapping

Within the above procedures, a highly valuable information is also contained, therefore, in order to apply the lean philosophy, it is important to be able to distinguish it. First and most important is the data itself, that is filled in the form, as in our times, data the most valuable commodity and its proper 'explanation' may provide invaluable insights. Values of operating temperatures, pressures, vessel's speed over ground and fuel oil consumption in comparison with the power output and other suchlike data are extremely important and must be transmitted effectively, intact and with confidentiality at the ship manager's/ owner's possession.

Next, another critical part for achieving the proper exploitation of the input data as: transformation to trends, equations and diagnostics, reviewing the overall efficiency of the propulsion installation and each individual machinery (turbocharger, auxiliary blowers, cooling and lubricating systems etc.) or even the fuel's quality. In order to accomplish the above, data should be in the proper condition, obtainable and usable, which means that the person in charge to collect it, as the collection is manual-matic, should be familiar and record the proper/correct values. In other words, Ch. Engineer's presence, in the collection process, is mandatory, to provide accuracy and the required corrections when needed.

Another value adding procedure that is contained within that process is the timeframe, in which the form will be filled. The quickest the data is gathered the better representation of the actual state of the engine. A useful example of such case, is the fuel parameters that are required, temperature of the fuel to be injected for the combustion, added with the respective pressure, fuel type (MGO, HFO, LSHFO etc.) and its respective specifications (such as Calorific Value, Density at 15°C, Viscosity, Sulphur Content). All the aforementioned data, must be in order and fully matched, collected at the same time, as even 1°C difference on the fuel temperature before injection or 50 kcal/kg difference in the fuel's calorific value, is capable to provide erroneous diagnostics for the oily water separator settings/use or the Main Engine's overall efficiency, respectively.

Closing, it is imperative to state that the adequate data extraction, preservation, recordkeeping and ultimately, analysis is the scope of this form and the suggested process, hence it is some short of challenging to distinguish which part is critical or not, as is seems that the whole data-keeping process is unavoidable, but has room for improvement though restructuring and shortcuts.

4.6.4 Stage 4: Creative Brainstorming

Creative brainstorming is the stage when all the above stages are translated to constraints, parameters and desired outputs, in order to develop the proper filtration process and finally reform the process, customized to the company's needs and operating values. That part is done through the author's presence within the company, after conducting a series of discussions and meetings with various employees and they all converged that the new process shall be characterized by the digitalization of the data and the data collection process. The manual-matic collection is a common ground of avoidance for all technical superintendents and crew onboard, thus the Suggested Process presented above is an effort towards that direction. The prime concept of subject thesis was the digitalization of ISM, with the transformation of the form, from manual entries to be automatic through the utilization of the AMS and the company's ERP platform, therefore the brainstorming stage is skipped.

Mark O'Neil, the President of Columbia Shipmanagement, which is one of the largest independent ship managers in the world, with more than 380 vessels under management and 15000 employees worldwide, said in an interview "**Digitalization is not a revolution. It is a natural evolution**". Explaining, the use of digital means in daily life and business environment is here to optimize the services provided and the overall promotion of safety at all levels. O'Neil, M. (2019, November) Interview with Kapetanakis P. for NAFTIKA CHRONIKA

4.6.5 Stage 5: Implementation

At this point, the exact steps of the implementation campaign will be presented, as the Digitalization of the ISM Forms, is an actual company's project, for 2019-2020, together with subject's thesis author. The most important part of this stage is to map the required values by the form, with the corresponding .csv exports of the AMS Tags, which means that an extensive search took place within a list of more than 6500 sensors and gauges outputs. An example of the AMS Tags format is shown on Table 7. Example of the Tag Summary Report of the AMS Export, where various pressures and scavenge air temperatures, per cylinder are presented. The data type that is contained in each column of the table and how data is transmitted within the DPU and AMS cable network, is explained below:

- **Tag**: is the name that is assigned by the AMS system designer to each DPU input signal, for reference. (e.g. ME136, which means that this input is from Main Engine)
- **Description**: is a brief description of the input signal (e.g. M/E J.C.W INLET PRESS.LOW, which is the Main Engine's Jacket Cooling Water Inlet Pressure, accompanied by the word LOW which means that if the specific input decreases to a certain value, at this case lower than 3.3 kg/cm^2, an alarm will sound)
- **Value**: the actual value of the input signal (e.g. 8.54)
- **Unit**: the unit used for measurement, if applicable (e.g. kg/cm^2)
- **Signal Type**: the type of signal that the specific sensor uses to transmit the data (e.g. 4-20 mA)

The Signal Types that are commonly used by a sensor to transmit data to DPU and then to AMS, are:

- **PT**: Pressure Transmitter, 4-20 mA, 2-wires type signal
- **PS**: Pressure Switch, On/Off contact signal
- **DPT**: Differential Pressure Transmitter, 4-20 mA, 2-wires type signal
- **DPS**: Differential Pressure Switch, On/Off contact signal
- **TT**: Temperature Transmitter, PT-100 ohm 2 or 3-wires type signal
- **TC**: Thermo Couple, 4-20 mA, 2-wires type signal
- **TS**: Temperature Switch, On/Off contact signal
- **LT**: Level Transmitter, 4-20 mA, 2-wires type signal
- **LS**: Level Switch, On/Off contact signal
- **FT**: Flow Transmitter, 4-20 mA, 2-wires type signal
- **FS**: Flow Switch, On/Off contact signal
- **XC**: Electric On/Off contact signal
- **PU:** RPM Pick-Up sensor, 4-20 mA, 2-wires type signal
- **OD:** Oil Detector

It is also interesting to note, that the majority of signals use the 4-20 milliampere range of electric current, which means two things, that the respective sensors utilize an inductive position gauge and that the minimum current is 4, greater than 0, in order for the system to be able to recognize the erroneous signal in case of failure, when the current will be 0.

Table 7. Example of the Tag Summary Report of the AMS Export

Tag	Description	Value	Unit	Signal Type
SPM15	M/E HFO INLET FLOW	330	kg/h	4 - 20 mA out
SPM16	M/E HFO FLOW TEMP	85.0	°C	4 - 20 mA out
ME135	M/E F.O INLET PRESS.LOW	8.54	kg/cm2	4 - 20 mA
ME136	M/E J.C.W INLET PRESS.LOW	4.07	kg/cm2	4 - 20 mA
ME136.1	M/E J.C.W OUTLET PRESS.LOW	3.04	kg/cm2	4 - 20 mA
ME137	M/E EXH V/V AIR INLET PRESS LOW	6.70	kg/cm2	4 - 20 mA
ME138	M/E SCAV.AIR RECEIVER PRESS	0.11	kg/cm2	4 - 20 mA
ME139	M/E STARTING AIR INLET PRESS LOW	28.03	kg/cm2	4 - 20 mA

Tag	Description	Value	Unit	Signal Type
ME140	M/E CONTROL AIR INLET PRESS LOW	6.67	kg/cm2	4 - 20 mA
ME156	M/E L.O INLET PRESS.LOW	2.64	kg/cm2	4 - 20 mA
ME178	M/E INLET VISCOSITY HIGH/LOW	11.1	cSt	4 - 20 mA
ME111	M/E NO.1 CYL.SCAV.AIR BOX TEMP H	44.7	°C	PT100 subtype 0
ME112	M/E NO.2 CYL.SCAV.AIR BOX TEMP H	43.6	°C	PT100 subtype 0
ME113	M/E NO.3 CYL.SCAV.AIR BOX TEMP H	45.5	°C	PT100 subtype 0
ME114	M/E NO.4 CYL.SCAV.AIR BOX TEMP H	44.2	°C	PT100 subtype 0
ME115	M/E NO.5 CYL.SCAV.AIR BOX TEMP H	43.9	°C	PT100 subtype 0
ME116	M/E NO.6 CYL.SCAV.AIR BOX TEMP H	45.4	°C	PT100 subtype 0
ME117	M/E NO.1 T/C L.O OUTLET TEMP. H	45.0	°C	PT100 subtype 0
ME118	M/E NO.2 T/C L.O OUTLET TEMP. H	44.9	°C	PT100 subtype 0
ME119	M/E F.O INLET TEMP HIGH/LOW	120.7	°C	PT100 subtype 0
ME120	M/E SCAV. AIR RECEIVER TEMP. H	38.4	°C	PT100 subtype 0

Having acquired the AMS Tags exports for the respective cells of the Main Engine Performance Report, Form EO-173, the next step is to create an analytical mapping of the signal and where exactly should be directed, in order for the company's Development Department to use it to parse the data into company's servers, edit it accordingly (conversions, combinations etc.) and the fill the form upon user's request. An example of the mapping that was created is shown on Table 8. Example of the Data Mapping between DPU/AMS and EO-173 Form, but its full version, along with more information and further analysis on its exploitation, can be found on Annex > Mapping.

- **Description**: The requested value of the company's EO-173 form (Main Engine Performance Report) to be filled.
- **EO-173 cell**: The respective cell of the EO-173 form, where the data, extracted from the AMS, will be presented.
- **AMS Tags:** The respective AMS tag which corresponds to the requested sensor/gauge's value.
- **Type/Unit:** The respective type of the data input and the relevant unit, if it has a physical meaning.
- **Count (Y/N):** whether subject value has been successfully extracted from AMS export.
- **Comments:** Various informative comments made on the mapping process.

Table 8. Example of the Data Mapping between DPU/AMS and EO-173 Form

Description	EO-173 Cell	AMS Tag	Type/Unit	Count (Y/N)	Comments
Exhaust Gas Temperature Cyl. 1	G54	ME101	[°C]	Y	M/E No 1 Cyl. Exh gas Aft Exh V/V
Exhaust Gas Temperature Cyl. 2	H54	ME102	[°C]	Y	M/E No 2 Cyl. Exh gas Aft Exh V/V
Exhaust Gas Temperature Cyl. 3	I54	ME103	[°C]	Y	M/E No 3 Cyl. Exh gas Aft Exh V/V
Exhaust Gas Temperature Cyl. 4	J54	ME104	[°C]	Y	M/E No 4 Cyl. Exh gas Aft Exh V/V
Exhaust Gas Temperature Cyl. 5	K54	ME105	[°C]	Y	M/E No 5 Cyl. Exh gas Aft Exh V/V
Exhaust Gas Temperature Cyl. 6	L54	ME106	[°C]	Y	M/E No 6 Cyl. Exh gas Aft Exh V/V

Description	EO-173 Cell	AMS Tag	Type/Unit	Count (Y/N)	Comments
Cooling Water Outlet Temp. Cyl. 1	G55	ME127	[°C]	Y	M/E NO.1 J.C.F.W OUTLET TEMP. H
Cooling Water Outlet Temp. Cyl. 2	H55	ME128	[°C]	Y	M/E NO.2 J.C.F.W OUTLET TEMP. H
Cooling Water Outlet Temp. Cyl. 3	I55	ME129	[°C]	Y	M/E NO.3 J.C.F.W OUTLET TEMP. H
Cooling Water Outlet Temp. Cyl. 4	J55	ME130	[°C]	Y	M/E NO.4 J.C.F.W OUTLET TEMP. H
Cooling Water Outlet Temp. Cyl. 5	K55	ME131	[°C]	Y	M/E NO.5 J.C.F.W OUTLET TEMP. H
Cooling Water Outlet Temp. Cyl. 6	L55	ME132	[°C]	Y	M/E NO.6 J.C.F.W OUTLET TEMP. H
Piston Cooling Lub. Temp. Cyl. 1	G56	ME143	[°C]	Y	M/E NO.1 P.C.O OUTLET TEMP HIGH
Piston Cooling Lub. Temp. Cyl. 2	H56	ME144	[°C]	Y	M/E NO.2 P.C.O OUTLET TEMP HIGH
Piston Cooling Lub. Temp. Cyl. 3	I56	ME145	[°C]	Y	M/E NO.3 P.C.O OUTLET TEMP HIGH
Piston Cooling Lub. Temp. Cyl. 4	J56	ME146	[°C]	Y	M/E NO.4 P.C.O OUTLET TEMP HIGH
Piston Cooling Lub. Temp. Cyl. 5	K56	ME147	[°C]	Y	M/E NO.5 P.C.O OUTLET TEMP HIGH
Piston Cooling Lub. Temp. Cyl. 6	L56	ME148	[°C]	Y	M/E NO.6 P.C.O OUTLET TEMP HIGH

Therefore, the vessel's sensors and gauges will transmit their signal continuously to the Distributed Processing Unit, DPU, which will work out and edit the data to be transmitted to Alarm and Monitoring System, AMS, to centralize all available information and export it in a .csv document and send it, in pre-designed time intervals, to the office and store it to the company's servers. Then, having all the required data available in the databases (sparsing data from .csv to database), the respective code, will use the mapping table to match the incoming sensors' values to the respective cells of the form.

After completing the mapping and the code is available by the Development Department, next step is to proceed with the transformed process's actual implementation on a vessel's ISM form. In particular, the vessel which was selected is the Dynamic Positioning Shuttle Tanker, LISBOA (IMO: 9765158), a suezmax with the capacity of 157,000 DWT, which trades in Brazil, repeatedly loading cargo from Floating Production Storage and Offloading (FPSO) units and discharging in various nearby areas. The reason that this specific vessel was chosen, is that due to its ability to keep a dynamic positioning, the ship is equipped with a very wide range of highly advanced sensors that enables the shipmanager to extract a lot of data without the need of installing additional equipment.

All the above information has been collected by the Piping Diagram in Engine Room, an example of which is shown in Figure 55, along with the vessels Alarm and Monitoring System mimics, as shown in Figure 47, Figure 48, Figure 49, Figure 50, Figure 51, Figure 52, Figure 53, Figure 54, Figure 55. Main Engine Fuel Oil Service System Piping Diagram.

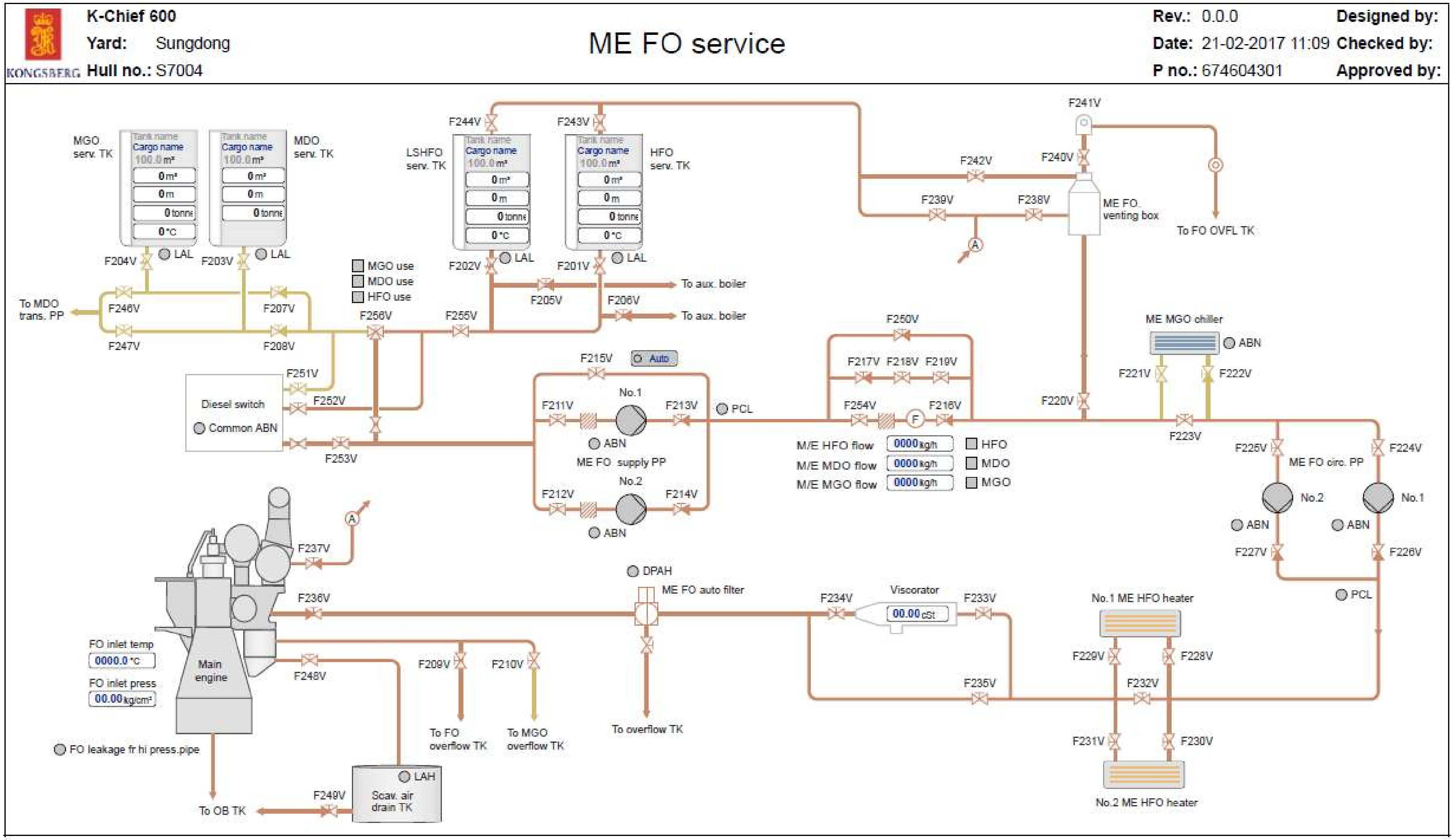


Figure 47. Main Engine's Fuel Oil Service Lines & Sensors

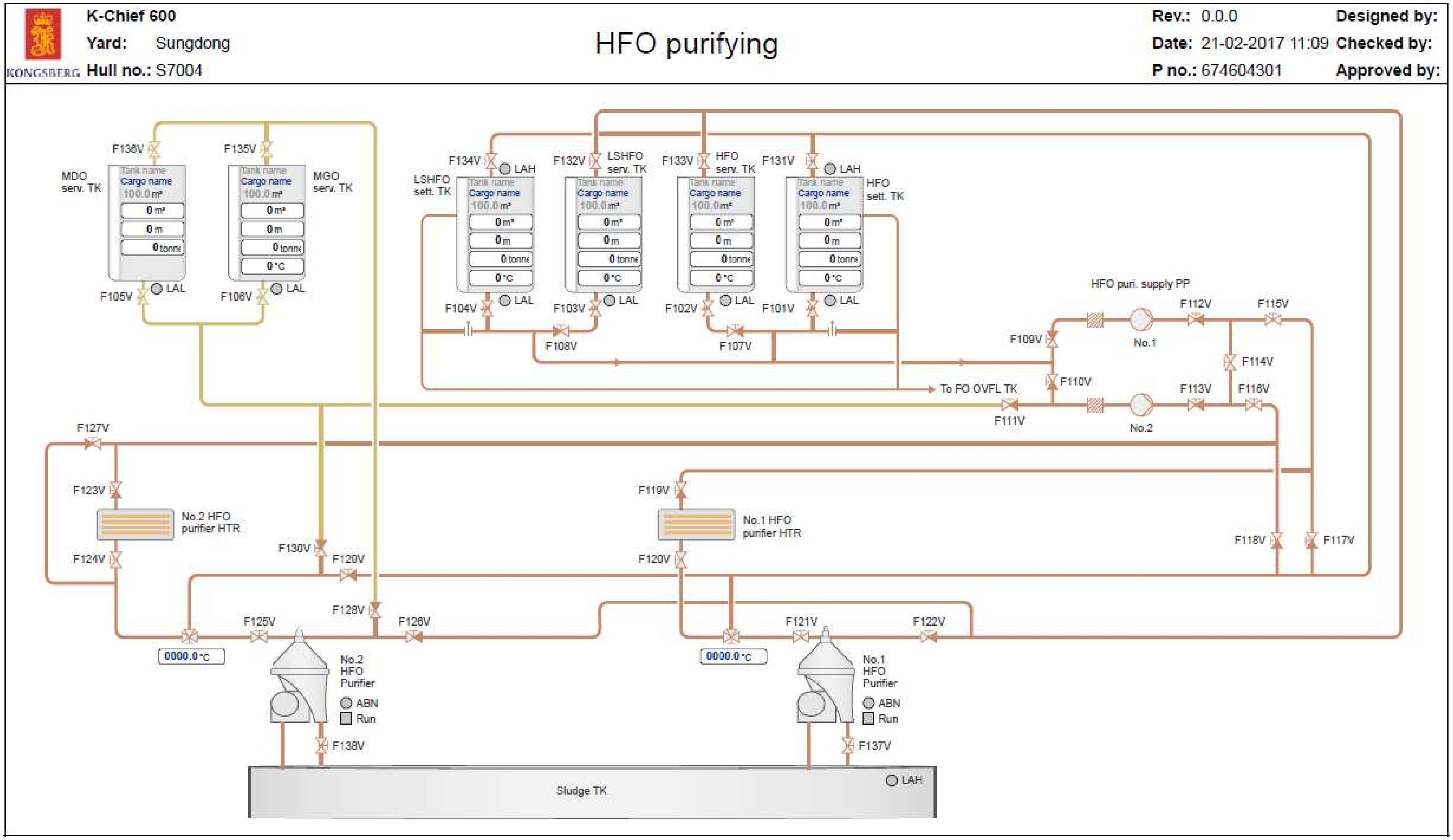


Figure 48. Heavy Fuel Oil Purifying System

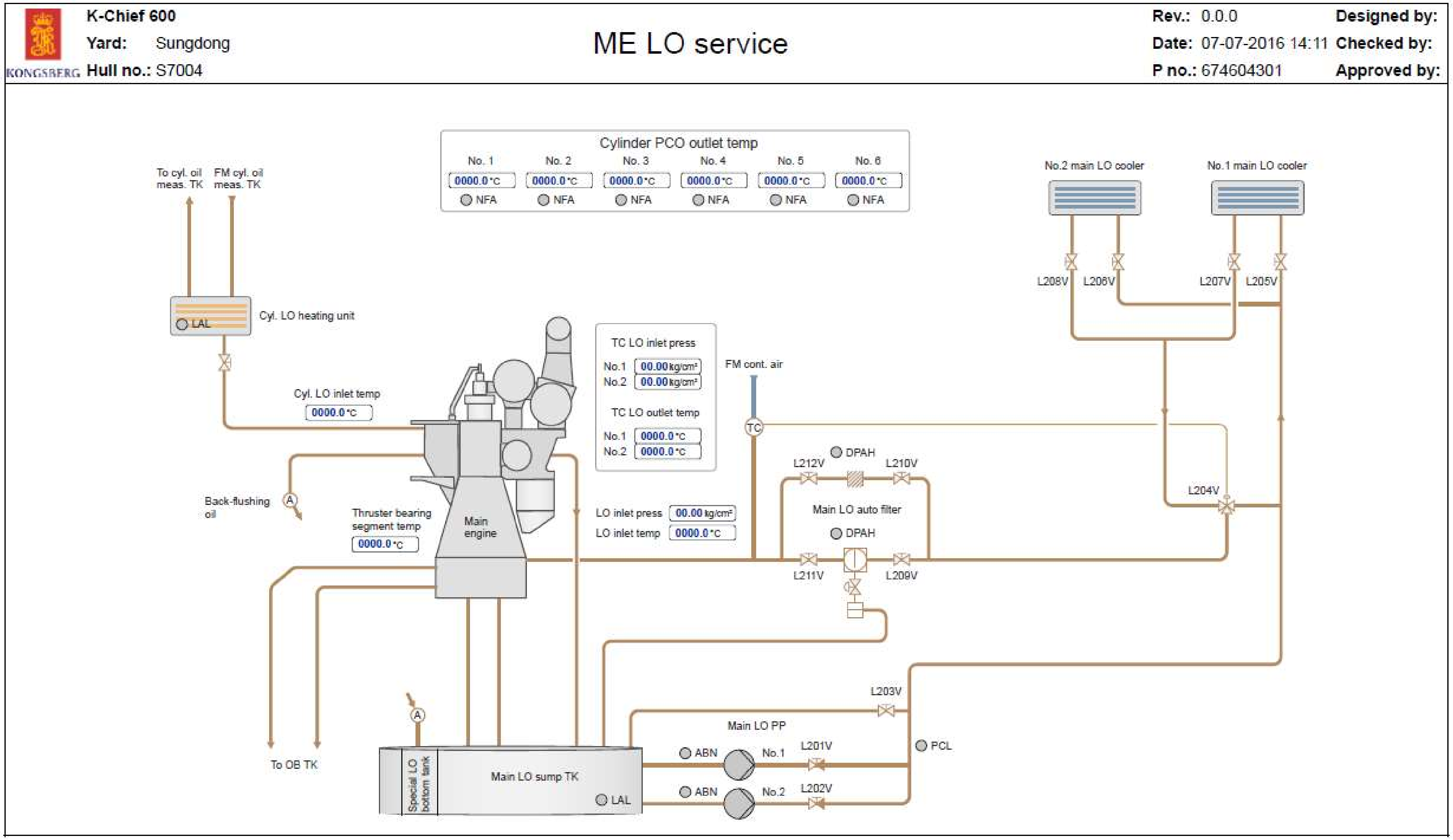


Figure 49. Main Engine's Lubricating Oil Service Line & Sensors

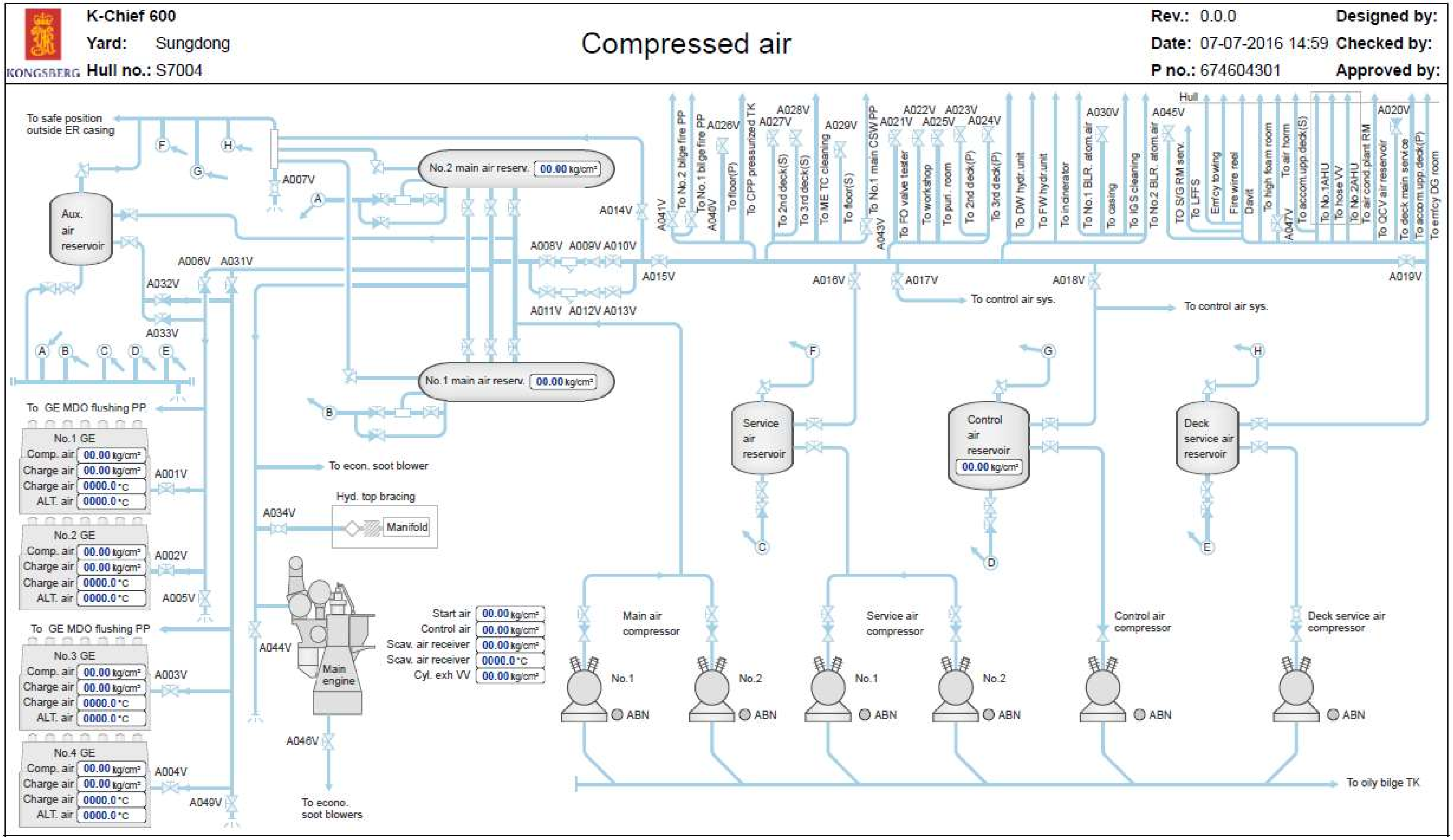


Figure 50. Compressed Air System

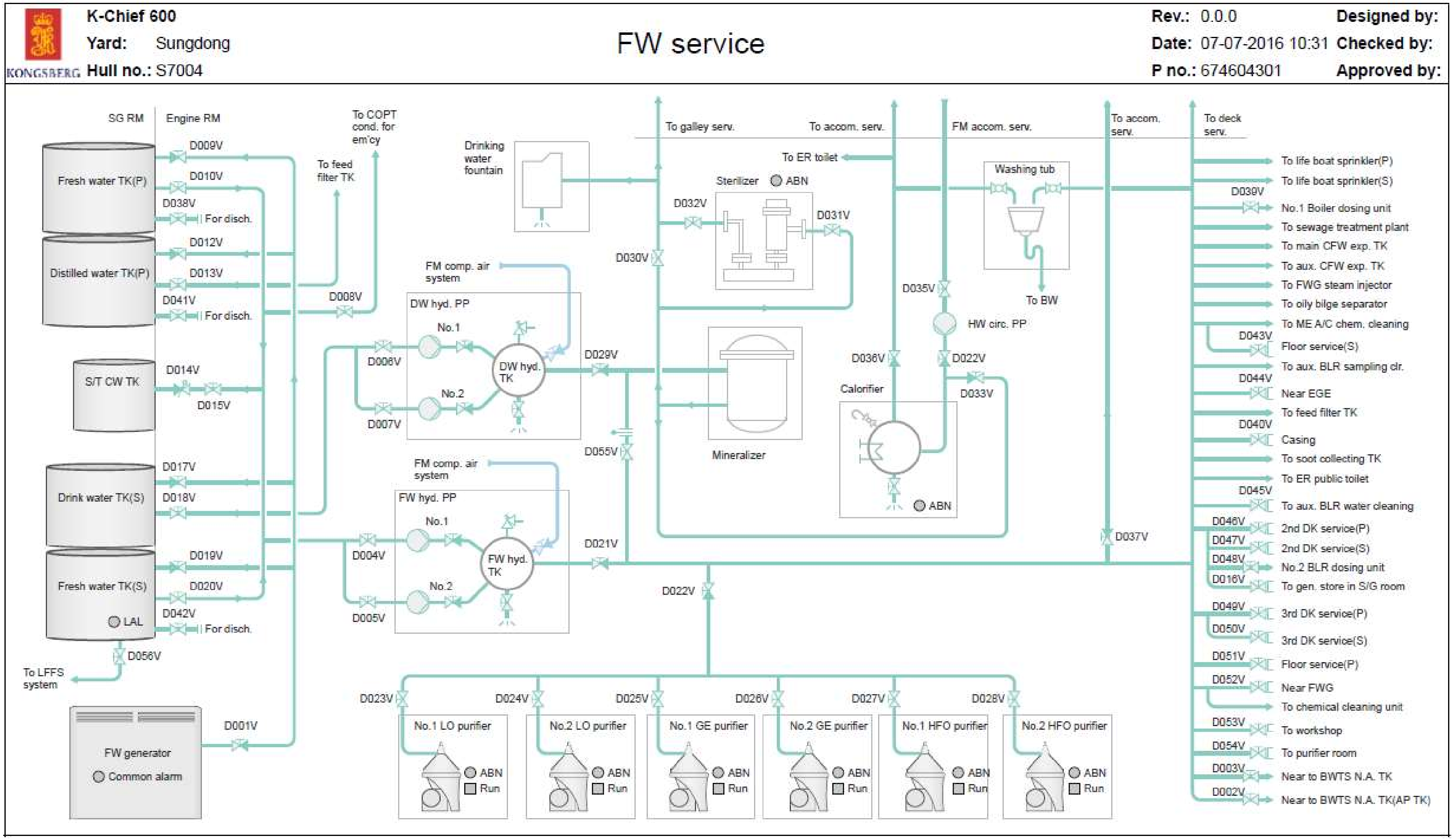


Figure 51. Fresh Water Service Line

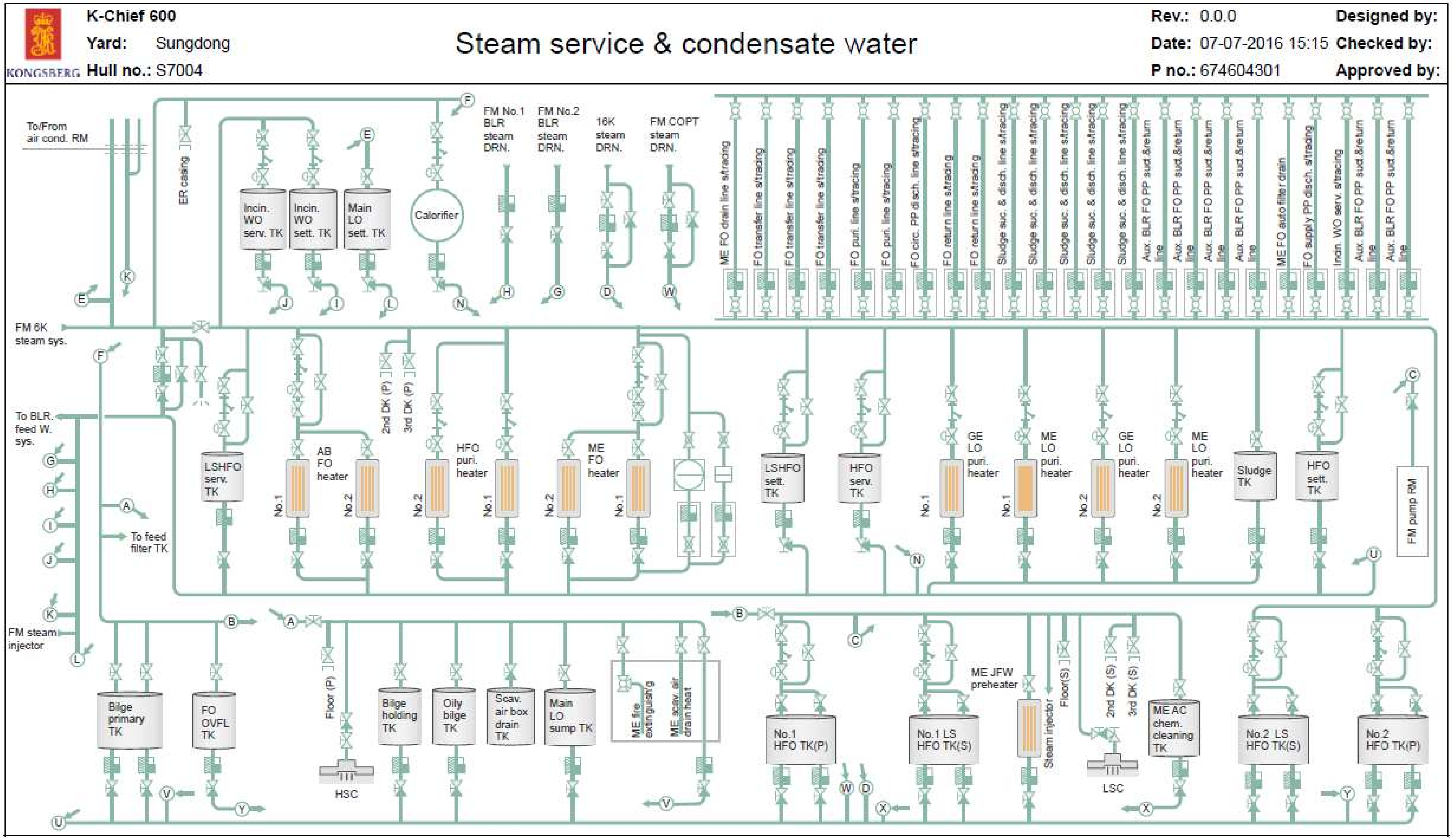


Figure 52. Steam & Condensate Water Service Line

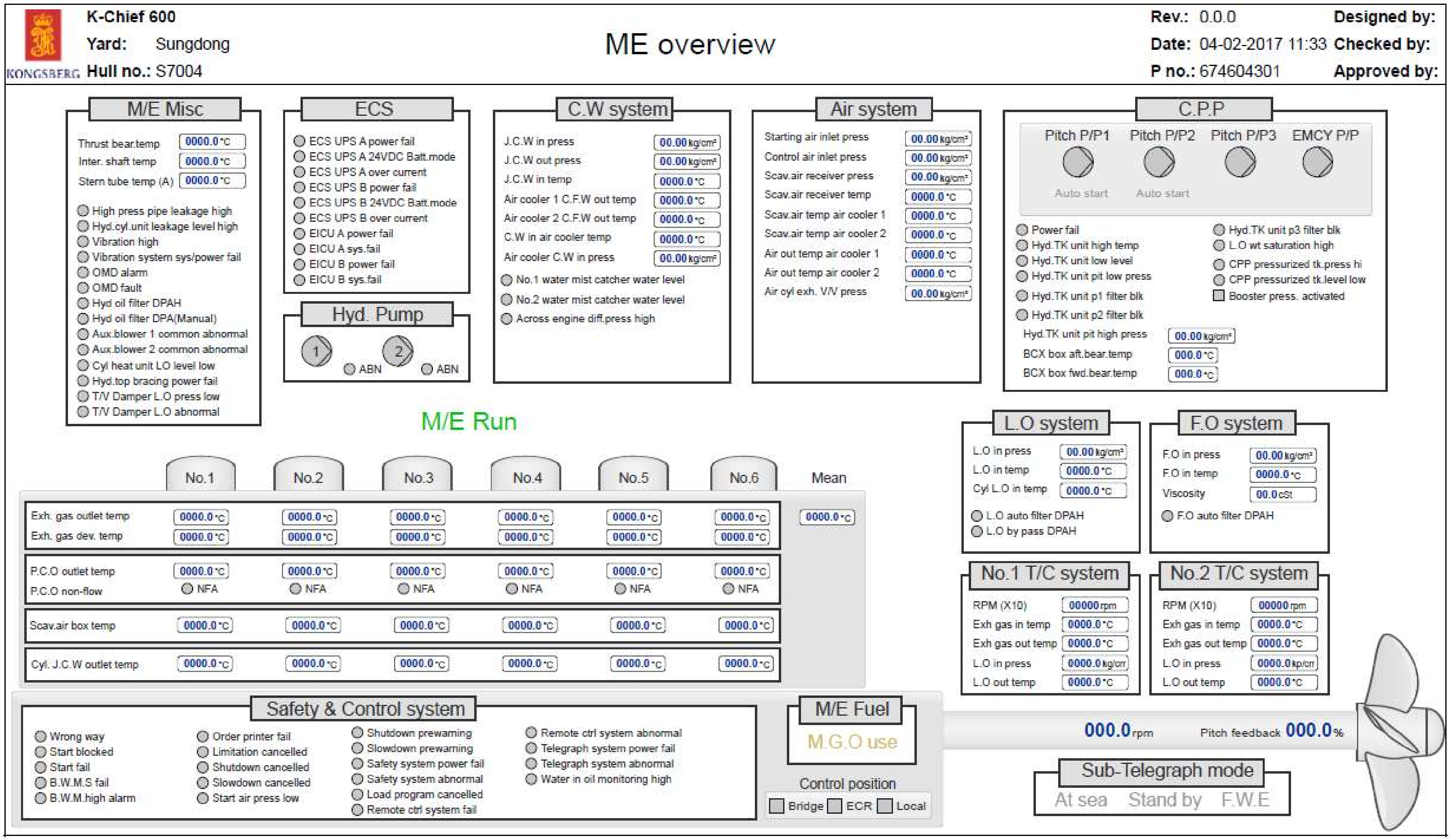


Figure 53. Main Engine Overview function (Sensors & Gauges)

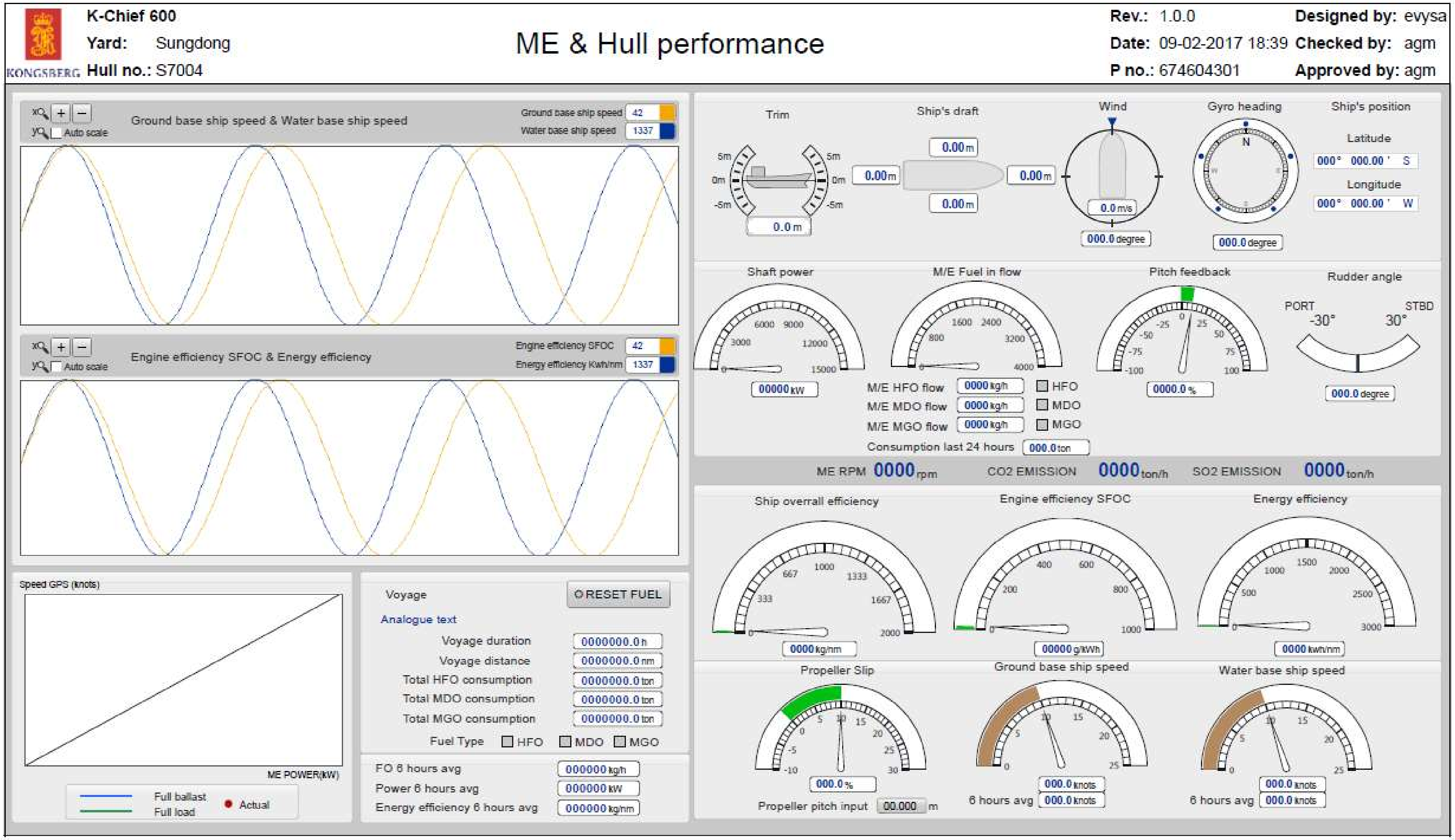


Figure 54. Main Engine & Hull Performance Monitoring function (Sensors & Gauges)

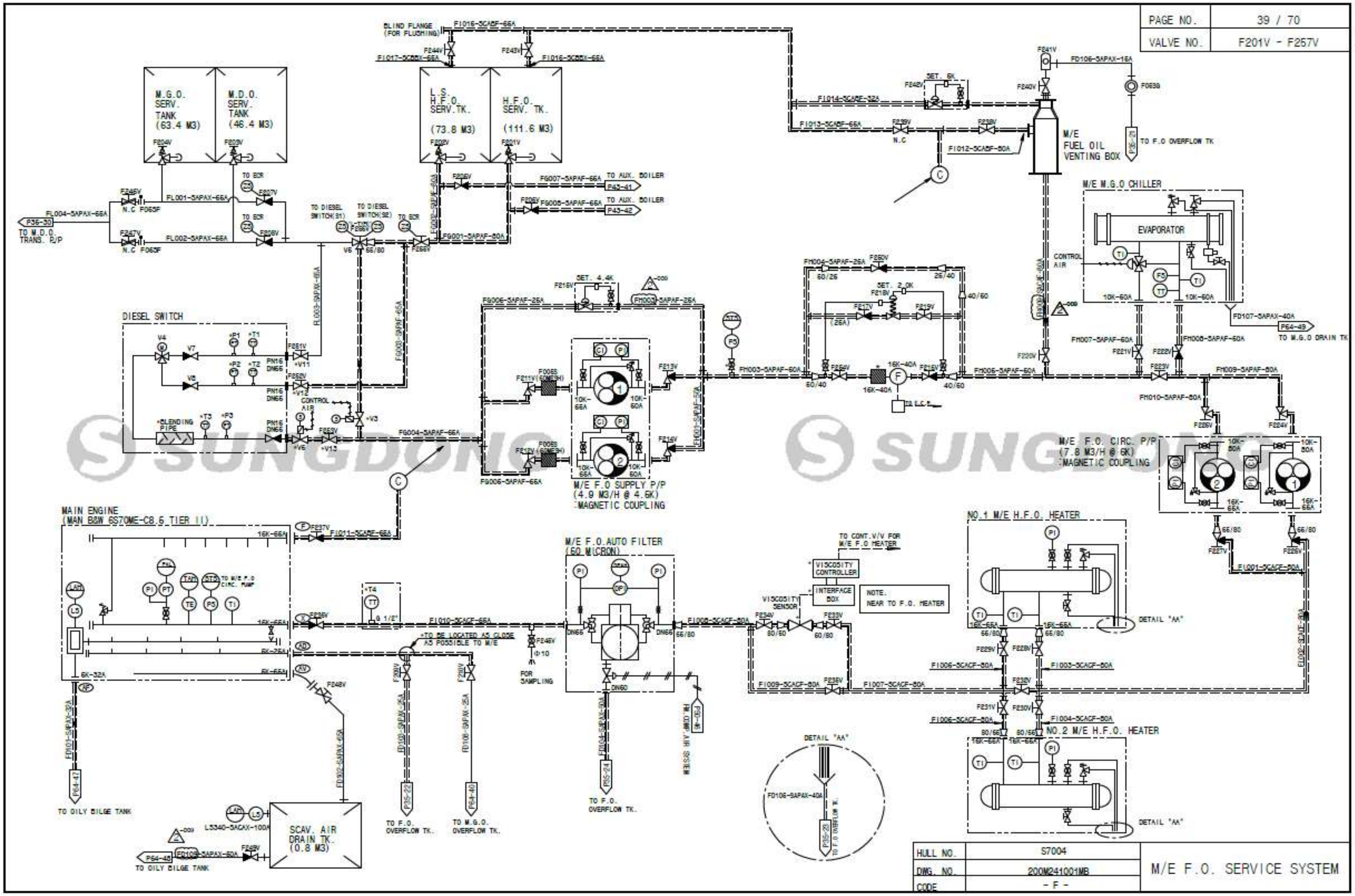


Figure 55. Main Engine Fuel Oil Service System Piping Diagram

5 Evaluation & Results

5.1 Process Overview

The overall work of subject thesis, focused on the development of a methodology to allow a company, and specifically a shipping company, to investigate whether various systematic processes have the potential for a substantial improvement in their inner body, as well as an implementation of that methodology on a specific ISM form for the reporting of a vessel's Main Engine's performance. It was made clear that the margin for improvement was considerable, as the majority of the processes prescribed by the ISM Code and respectively the SMS, are obsolete, due to the industry's heavy burden of high safety standards and as a result the extensive bureaucracy.

At this section, having already applied the Lean Transformation of a current process, a results' evaluation method is presented, in order to define its success. It is important to be noted that the goal of the transformation was to restructure it, making it as lean as possible using only existing equipment and modifications of the existing systems, with no additional costs for the owner/shipmanager. Therefore, in case a fund was available to install all required equipment the overall success of such application would easily reach 100%, scenario which is almost impossible at the current situation of the market, as the majority of sensors that would be needed would provide no actual added-value to the customer in short-term analysis, but only to the investigation of a lean transformation. In other words, reaching the maximum of 100% implementation of the transformation would require a significant amount of capital and, respectively, an extensive cost-benefit analysis in a long-term horizon.

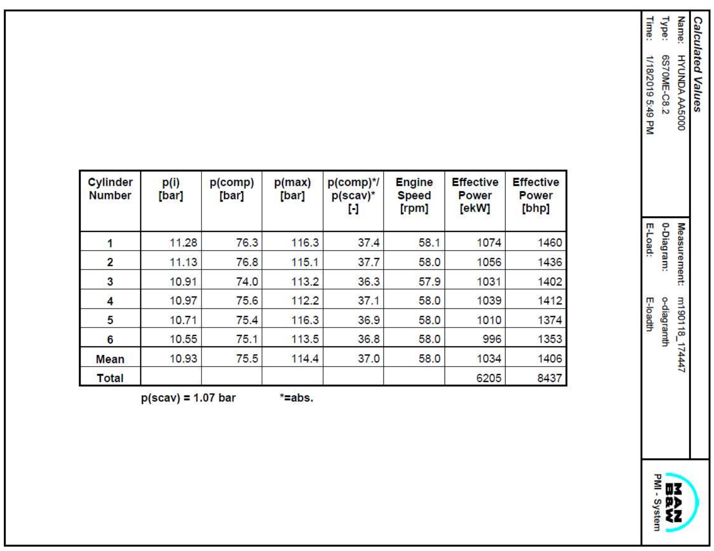
From a different perspective, in case of a newly opened company, which would require to design its Safety and Quality Management systems from scratch, the implementation of lean methodology would have a high performance results, ordering new building vessels with all the required values/data available electronically, rather than a company which already owns 100 vessels with an average age of 10 years old, to retrofit them with the required sensors.

Recently, in the TSAKOS Group's 'European Officers Forum', which took place in Athens, on the 1st and 2nd of November, 2018, an annual event where all European crew members and office personnel are getting together to exchange valuable feedback and insights of the day to day tasks and overall performance of the company, a substantial part of the Chief Engineers, highlighted the bureaucratical process of the data collection procedures, even if such procedures exist to ensure the safe working environment. What was aimed to be achieved by subject thesis, was an investigation of the reduction of voluminous and time consuming procedures for the data collection and at the same time a substantial increase in the accuracy of the data received as well as its time intervals, for adequate recordkeeping and trending analysis. The benefits of that investigation, which will continue to expand, within the company, are about to be explored within a 5-year horizon, in which the project is aimed to be implemented fleetwide, as far as practically possible.

5.2 Specific Results

Following Stage 5, the Lean Transformation Evaluation and as per the full mapping document, which is attached on the Annex, it is calculated, that through the AMS export or vessels library (sea trials, model tests, manuals, drawings and plans), the digitalization was implemented on a **59.5% rate**, which translates that **6 out of every 10 values** of the form were successfully filled by a digital process, with no manual collection of the required data. That was made possible by using only already-available means, which means that the room for further improvement is excessive.

In addition, a wide range of engine's performance data (Indicative, Maximum and Compression Pressure, Fuel Index Offset High and Low Load, Maximum Pressure Adjustment, Compression Ratio and Exhaust Valve Open Timing, all values for each different cylinder), 48 out of 180 in total, were found to be available in the vessel's system, but not ready to be imported in the DPU and AMS, as the measurements are being taken by the built-in the machineries systems, in the specific case the system is called CoCos EDS (Computer Controlled Surveillance – Engine Diagnostics System) from MAN B&W and data is being exported as a separate .pdf file, as shown below in the Figure 56. Calculated Values ,Figure 57. Balance Graphs ,Figure 58. PV Diagram and Figure 59. PT Diagram In order to include these sensors' exports, the company has initiated discussions with their maker, aiming to direct all available signals in a central processing unit, which will then transmit them directly to the office, as they are already available onboard but in a different server.



Cylinder Number	p(i) [bar]	p(comp) [bar]	p(max) [bar]	p(comp)*/ p(scav)* [-]	Engine Speed [rpm]	Effective Power [ekW]	Effective Power [bhp]
1	11.28	76.3	116.3	37.4	58.1	1074	1460
2	11.13	76.8	115.1	37.7	58.0	1056	1436
3	10.91	74.0	113.2	36.3	57.9	1031	1402
4	10.97	75.6	112.2	37.1	58.0	1039	1412
5	10.71	75.4	116.3	36.9	58.0	1010	1374
6	10.55	75.1	113.5	36.8	58.0	996	1353
Mean	10.93	75.5	114.4	37.0	58.0	1034	1406
Total						6205	8437

p(scav) = 1.07 bar *=abs.

Figure 56. Calculated Values

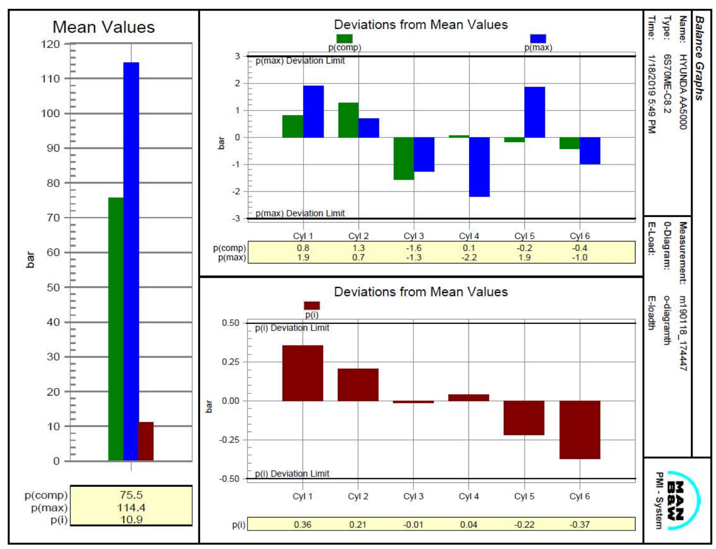


Figure 57. Balance Graphs

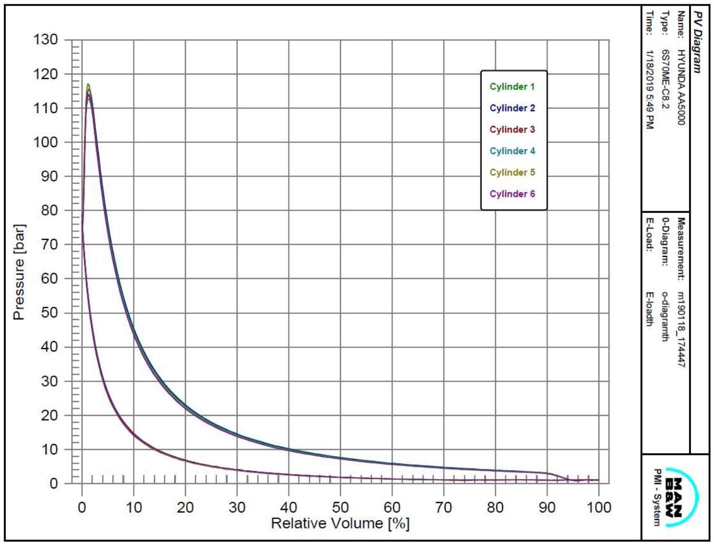


Figure 58. PV Diagram

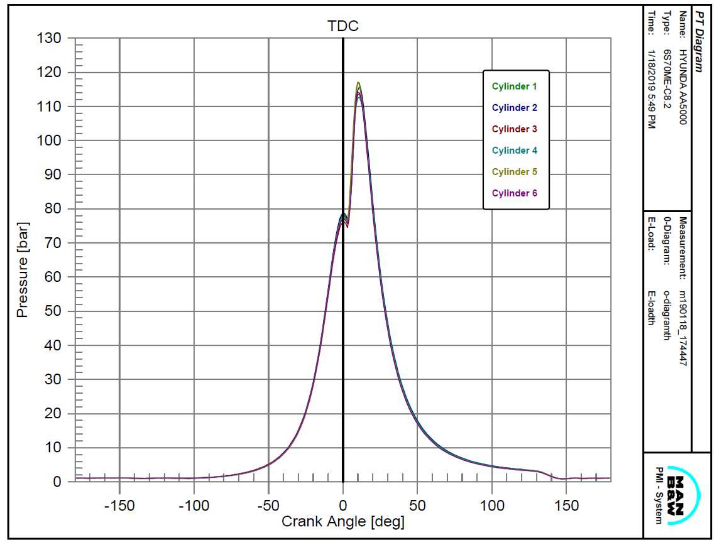


Figure 59. PT Diagram

Further to the above, an additional set of 5 values, in particular, fuel oil specifications were found that are available through the Lloyd's Register 'Fuel Oil Bunker Analysis and Advisory Service' or 'FOBAS', system. As the poor fuel quality can increases the risk of reduced operational and environmental performance, while also creates an unsafe working environment, the company is in collaboration with the Classification Society and after each bunkering operation, send a sample of the fuel to laboratories all around the world, to receive an independent verification of fuel quality with comparison to the international standards and environmental legislations, before the use of any fuel. An example of the aforementioned verification is shown in the Figure 60. Example of a FOBAS Fuel Analysis Report , while at the same time, all the data contained is also available in the company's server. As a result, a combination of multiple sources of information, can provide 5 additional values in the EO-173 Form.

The above expansion is not within the framework of a thesis essay, and is expected to take multiple discussions and meetings, between LR (Class) and Engine's Maker, for its completion, it is only calculated that if these values are also introduced to the AMS export, the rate of digital implementation on the form will reach the impressive value of **87%**, which would translate to almost **9 out of every 10 values** of the form have been successfully collected automatically, with no crew involved at all.

Considering the average completion time of such a form takes a minimum of 1 hour, the implementation of the transformed process for a single vessel would equal to a reduction of the human fatigue by 6 man-days per year. If this process is expanded along the company's fleet, which at the moment stands with **83 vessels**, the reduction would be **498 man-days** per year. It is important to note that these results are possible with the automation of a single form of the SMS. The automation and digital transformation of other time-consuming and frequently submitted forms is certainly a major inhibitor of the human fatigue onboard.

Lloyd's Register

Contact us

FOBAS Fuel analysis report

This report is also available at https://www.lrgmt.com where can see all your samples in transit, your analysis reports, client and global statistics, and other useful information. If you don't have access please contact us and we will arrange it for you.

Client: Tsakos Shipping

Our Ref: 190661211	**Report Status:** Green	
Vessel: Lisboa	**IMO: 9765158**	
Sample Dispatch Date:	2019-06-24	
Lab Receipt Date:	2019-06-28	
Courier Used:	DHL : 2108896731	
Dispatched From:	RIO DE JANEIRO - BRAZIL	
Sample	1	2
Port	RIO DE JANEIRO	RIO DE JANEIRO
Sampling Date	2019-06-16	2019-06-15
Supplier	PETROBRAS	PETROBRAS
Barge/Inst	OMS XVIII	CD SERRA DA ESTRELA
Sample Point Type	MANIFOLD	MANIFOLD
Sampling Method	DRIP	DRIP
Advised Bunker Details		
Viscosity cSt	339.2	3.9
Density @ 15°c kg/l	0.9691	0.8533
Sulphur	1.20	0.40
Quantity MT	1400.085	750.088
Seal Number Lab	2109394	2109899
Tag Seal Numbers Lab	2507851	2507856
Seal Number Vessel	2507852	2507857
Seal Number Supplier	2507853	2507858
Seal Number MARPOL	94618	91054

Figure 60. Example of a FOBAS Fuel Analysis Report

5.3 Evaluation

As by October 2019, all the results and process of above investigation were set in motion, therefore the actual evaluation and the transformed process's performance will be assessed in practice, with feedback from the officers and engineers onboard. For the framework of the thesis, though, several criteria by Vieira et al. (2007) and Greiner et al. (2007), which have been combined by Kuronen & Tapaninen (2010) and later implemented by Lappalainen et al. (2012), will be used, in order to provide a comprehensive evaluation framework and analyze the strengths and weaknesses of the new instrument developed. The criteria are shown on the Table 9. Evaluation Criteria, Brief Descriptions and Further Analysis, along with their corresponding explanation on the SMS process's implementation.

Following the implementation of the transformed process, an evaluation from the related parties is of paramount importance. At this stage, the relevant criteria were presented to the company's key personnel, along with the achievement and the respective results, and a brief survey took place, in order to effectively evaluate the overall importance and effectiveness of the transformation to be achieved.

Table 9. Evaluation Criteria, Brief Descriptions and Further Analysis

#	Criterion	Description	Further Analysis
1	Effectiveness and Appropriateness	The policy instrument must be suitable for achieving a desired goal	The transformed process shall be technically sufficient to replace the previous
2	Economic Efficiency	The benefits versus the costs of implementing the transformed process should be in balance	Assessment of the total benefits and defects, risk minimization and safety promotion
3	Acceptability	The policy instrument must be accepted by the stakeholders and the community	Definition of the acceptance level by the community, important for the long-term adoption of the process
4	Enforcement	The policy instrument can be implemented effectively	Practicality and effectiveness of the process's implementation, potential barriers to overcome
5	Incentive and Innovation Effects	The instrument encourages experimentation, change and provides an ongoing incentive for improvement	Adaptive development, use of new technologies and innovative thinking

The participants' group consisted of Technical Superintendents, Marine Superintendents, Development Team, Crewing Officers, HSQ Officers, Vessel Performance and Environmental Engineers, along with the company's DPA, Technical Manager, Technical Director, Managing Director and other owner's representatives. The total number of participants was 20. The sample of the personnel can be considered as very representative and with high levels of experience on relevant matters.

The number one question for all the participants was "Do you believe that ISM Digitalization is an effective method to reduce the crew's workload?", on which each and every one responded positively. This fact alone, is an indicative measure that such initiatives are part of the natural evolution of the industry. Next, the participants were requested to evaluate the presented transformed process with regard to the aforementioned criteria. From the group, 80% were males, 95% selected master's degree as their education level, while 20% were 25-34 years old, 45% were 35-44, 20% were 45-54 and 15% were over 55.

The responses are presented on Figure 61, in a rating from 0-10 with 0 translating to a failed approach and 10 to a top performance approach, followed by histograms for each different criterion, Figure 62. Histogram of Responses for Effectiveness, Figure 63. Histogram of Responses for Appropriateness, Figure 64. Histogram of Responses for Economic Efficiency, Figure 65. Histogram of Responses for Acceptability, Figure 66. Histogram of Responses for Enforcement, Figure 67. Histogram of Responses for Incentive, Figure 68. Histogram of Responses for Innovation. It should be noted, that the double criteria, such as criteria 1 and 5, were investigated separately and the results were averaged.

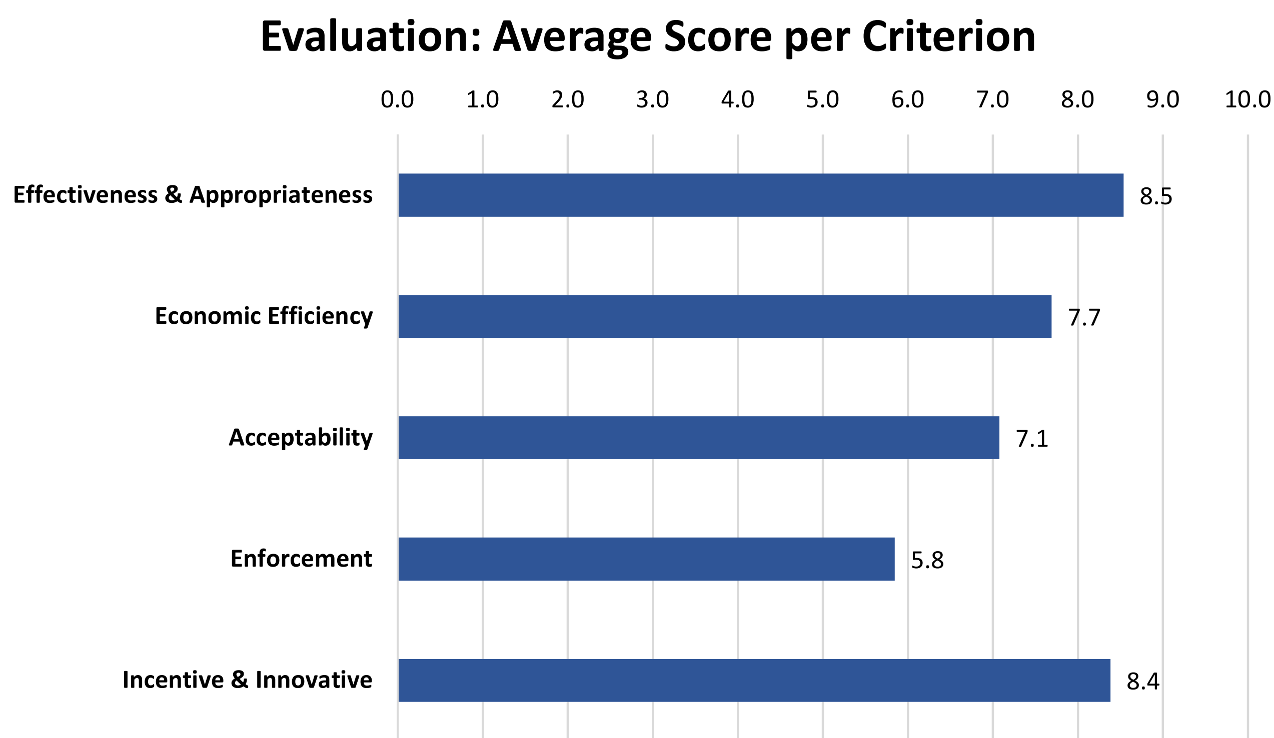


Figure 61. Average Scores of Evaluation

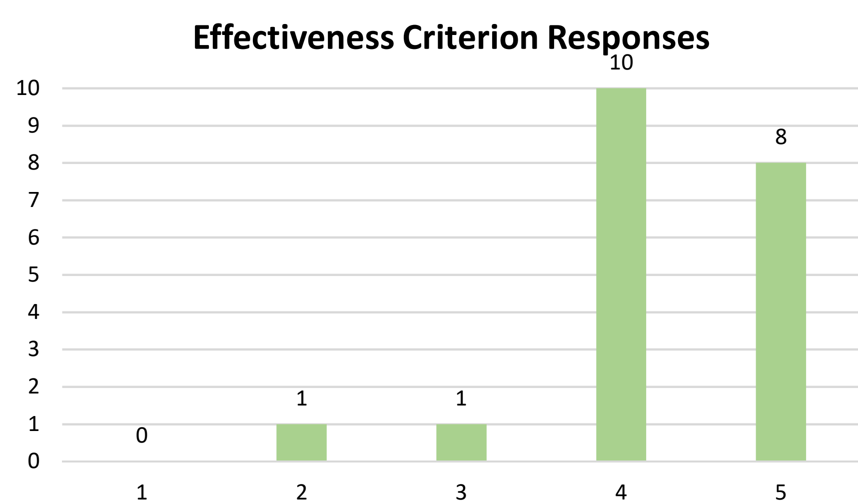


Figure 62. Histogram of Responses for Effectiveness

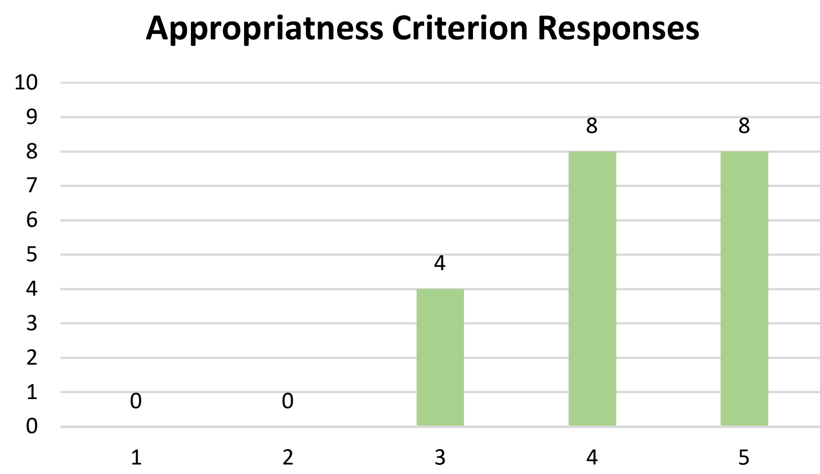


Figure 63. Histogram of Responses for Appropriateness

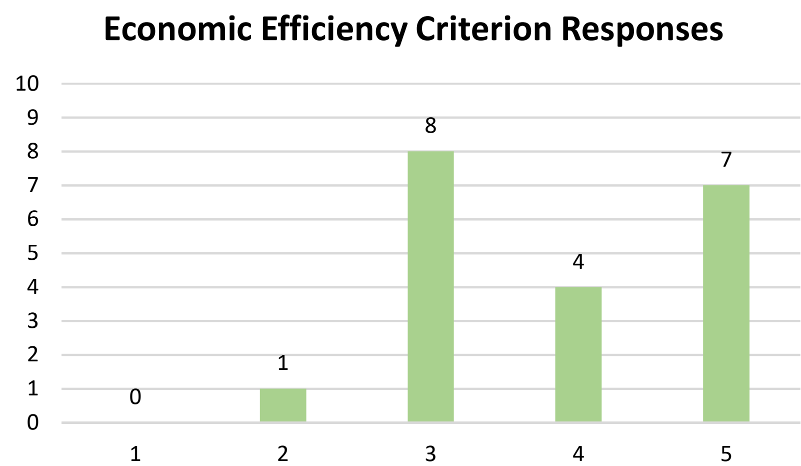


Figure 64. Histogram of Responses for Economic Efficiency

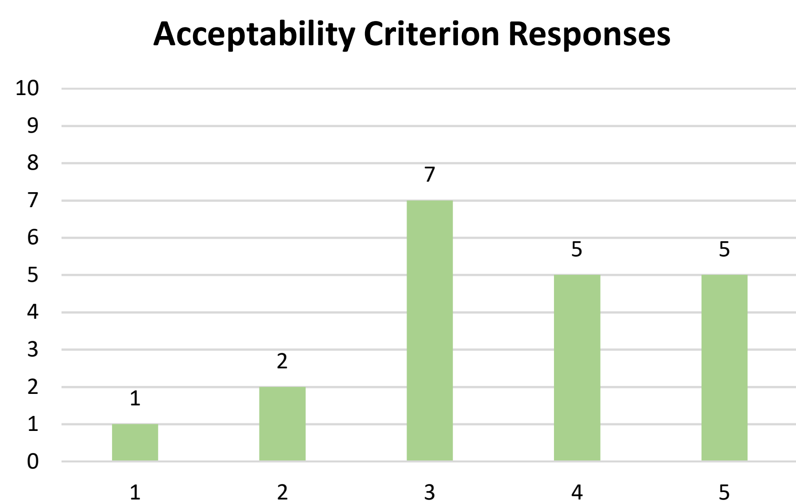


Figure 65. Histogram of Responses for Acceptability

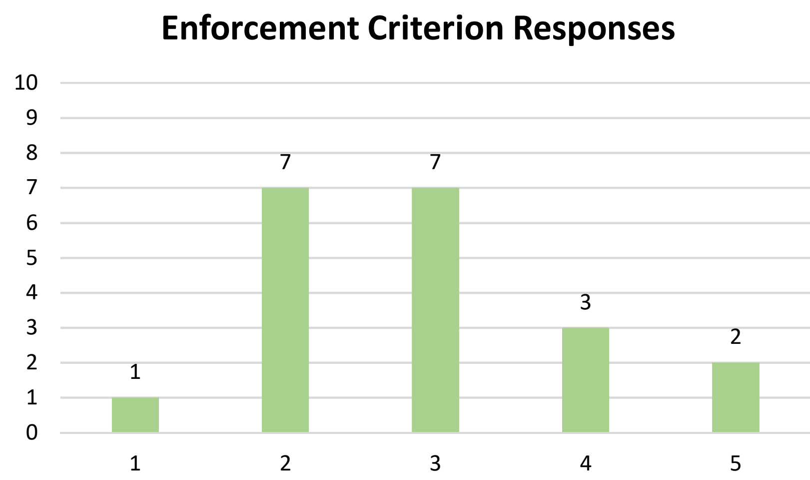


Figure 66. Histogram of Responses for Enforcement

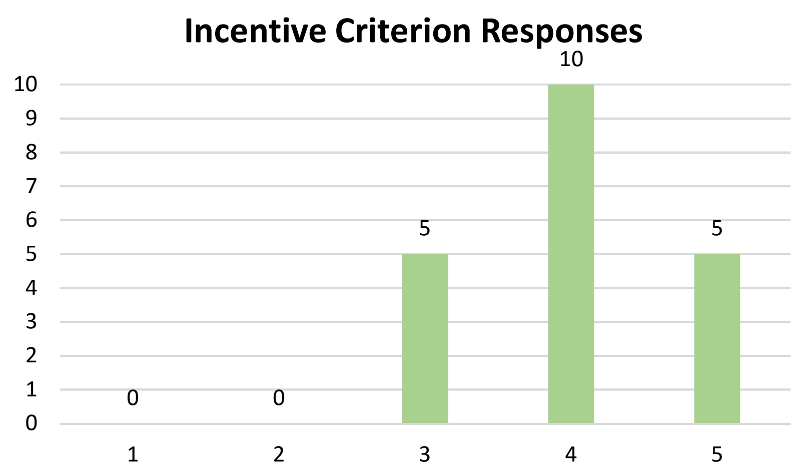


Figure 67. Histogram of Responses for Incentive

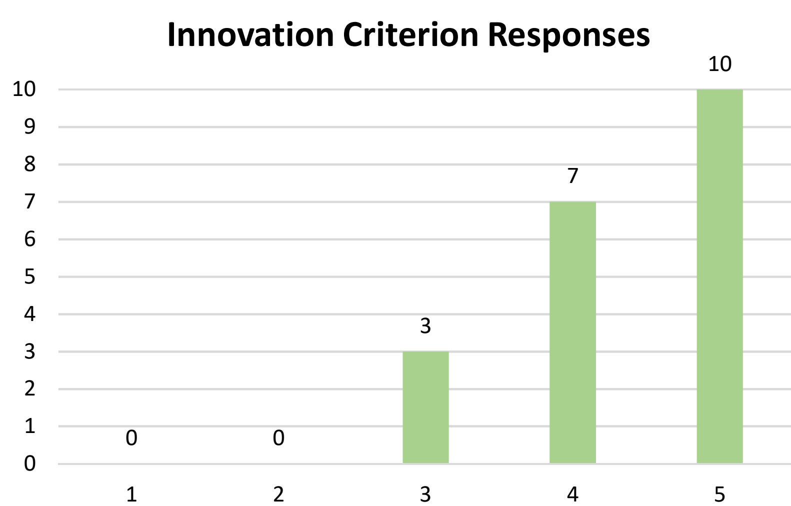


Figure 68. Histogram of Responses for Innovation

It is observed that the criteria with the lowest score is the enforcement, which in combination with the strong connection of the transformed process with advanced technological mediums, is fully anticipated. Explaining, the shipping industry has shown multiple times its slow-moving character with respect to technological progress and such transformation of a daily process towards semi-automation, would translate to 'quick steps' for the industry. In order to effectively enforce such process, steady upward steps are needed, to achieve a smooth transition to the new functional automated media for the vessels' monitoring. The overall evaluation of the transformed process is **7.5/10**, which is high considering its innovative character.

5.3.1 Effectiveness and Appropriateness

Despite the fact the ISM Code and subsequently the SMS design, have as a primary goal to improve maritime safety and increase the environmental damages prevention, a lack of quantitative studies regarding the impacts of the code within the industry has been noticed. Based on a report by ConsultISM Ltd (2008), there is a common unanimity of its positive contribution to safety increase, though. Therefore, the quantitative results of such an evaluation will have to be provided after a prolonged period of subject process's implementation (as stated above, within a 5-year horizon) through users' feedback.

However, through a qualitative approach, it is apparent that the transformed process achieves an overall replacement of 87% of the previous process and fully automates it, which translates to significantly reduced time for the crew to collect all the desired measurement from all around the engine room and various machineries (e.g. turbochargers, auxiliary blowers, fuel pumps, heaters, chillers, filters, valves etc.). At the same time, an extremely high level of accuracy is possible from the data collected, which allows both the crew and the office personnel to monitor, trend, and effectively maintain the machineries, while concurrently enables historical observations through an extensive database in the company's server, with valuable data.

As for the appropriateness of subject instrument, the worlds' markets make clear that progress of a system is measured by the best possible result with the least possible effort spent. In other words, as stated by Lappalainen et al. (2012), 'the amount of effort expended in achieving the results must be in proportion with the benefits gained'. Explaining, the previous procedure, had a fully manual data collection process which involved multiple hours of effort and expertise lost, while the output was only a rough representation of the engine's current state. The transformed process, when implemented, will require almost no expertise at all, due to automatic collection and a continuous track of the engine's states. As a result of the above, it can be assessed that the process transformation in terms of effectiveness is **successful**, especially taking under consideration the overall score of 8.5/10 on the survey.

5.3.2 Economic Efficiency

At this criterion, it is mandatory to state that specific quantitative results cannot be provided, since it is not within the scope of a thesis essay and would require a specific investigation focusing only in the cost-benefit analysis. For completeness purposes, it is stated that an economic efficiency analysis of the transformed process and any similar cost-benefit investigation, should take the vessel’s daily and annual expenses, as shown in Figure 69. Indicative Operating Costs 2018 ($ Per Annum) of a Suezmax Vessel Part 1 / Source: Drewry Report 2018-2019 and Figure 70. Indicative Operating Costs 2018 ($ Per Annum) of a Suezmax Vessel Part 2 / Source: Drewry Report 2018-2019 , within a period of at least 5 years and observe how repair & maintenance (R&M), spares, stores, insurances (H&M and P&I), manning, management, lubricating and fuel oil consumption costs have behaved, compared to a sister[11] vessel with no transformed process implemented. Even if the benefits of subject process, are easy to be understood, in a monetary approach also, it is extremely challenging to provide actual quantitative results, as it was noted by Lappalainen et al. (2012) that there are no feasible ways of evaluating the economic efficiency of the implementation of the ISM Code, due to the lack of systematic methods for recording safety costs, within the industry.

dwt	**150-160,000 (10-yr old)**
MANNING	
Officer/rating numbers	25
Crew wages and overtime	1,239,850
Crew victualling	72,370
Crew travel	66,880
Miscellaneous costs	124,340
Total	**1,503,440**
INSURANCE	
Hull & machinery	117,030
Protection & indemnity	141,690
War risk	12,310
FD&D	9,770
COFR	2,440
Total	**283,240**
STORES	
Deck & cabin stores	48,180
Safety Items/protective equipment	43,200
Chemicals and gases	14,950
Medical	6,650
Mooring wires & ropes & hoses	18,280
Crane wires	3,320
Maintenance paint	26,580
Tools & hardware	4,980
Transportation costs	0
others	0
Total	**166,140**

dwt	**150-160,000 (10-yr old)**
SPARES	
Main propulsion unit	45,050
Generator engines	29,450
Boilers	10,400
ER auxiliary machinery	29,450
Deck machinery	6,930
Electrical	8,660
Cargo & ballast system	13,860
Pipes & valves	3,470
Navigation equipment	5,200
Access equipment	3,470
Spares transportation	17,330
Total	**173,270**
LUBRICATING OILS	
ME cylinder oil	116,130
ME system oil	58,060
Aux engine oil	23,750
Engine room hydraulic oil	5,280
Cargo system hydraulic oil	5,280
Deck hydraulic oil	5,280
Other oils	21,110
Transportation costs	29,030
Gas & reefer compressors	0
Total	**263,920**

Figure 69. Indicative Operating Costs 2018 ($ Per Annum) of a Suezmax Vessel Part 1 / Source: Drewry Report 2018-2019

As it was stated above, the process’s transformation had the scope to investigate whether and in what extend it was possible to transform an existing process with **no additional funds and sources used**. Correspondingly, the **economic efficiency** of the new process can be evaluated (qualitatively only) as **high**, as an 87% part of the old process has been fully automated (or will be automated after several discussions and meetings with makers), with no additional costs. It is also important to note that the new process would not require a trained engineer to collect the data, resulting in two major advantages: 1) will allow more time for the Chief Engineer to perform his actual/practical tasks, maintaining and operating successfully the engine room 2) will reduce significantly the crew’s workload while, simultaneously, will not apply any further burden for

[11] Ships build by the same yard from the same plans with a deviation of ~1-2% of the lightship displacement, as per IMO resolution MSC/Circ.1158 in 2006

registrations and measurements in times of excessive workload (e.g. during Loading/Discharging and other operations). The overall score of this specific criterion on the survey that took place within the company was 7.7/10.

dwt	150-160,000 (10-yr old)
REPAIR & MAINTENANCE	
Main engine inc. re-conditioning	17,940
Boiler	1,890
Generators	16,990
ER auxiliaries	6,610
Cargo & ballast system inc. calibration	4,720
Electrical including rewinds	6,610
Pipes & valves & hydraulic systems	4,720
Deck machinery inc. cranes	6,610
Navigation equipment	8,500
Access equipment	6,610
LSA & FFE (Life saving appliances & fire fighting equipment)	13,220
Total	**94,420**
INTERMEDIATE/SPECIAL SURVEY	
Total	**434,580**

dwt		150-160,000 (10-yr old)
MANAGEMENT & ADMINISTRATION		
Fees & Services	Management Fee	160,120
	Launches & other transport	22,090
	Flag state inspection, certification & other charges	11,040
	Classification fee	11,040
	PSC charges	3,870
	Third party services	5,520
	Consulting fees	14,360
	Procurement costs	36,440
	Communications, printing, IT & postage	27,610
	Vetting	49,690
Sub-costs		**341,780**
Owner's Costs	Owners disbursement	22,090
	Masters entertainment	5,520
Sub-costs		**27,610**
Safety & Environmental Compliance	Internal auditing & inspection	5,520
	Training	2,210
	Survey & calibration of equipment	22,090
	Incinerator servicing & maintenance	3,310
	OWS servicing & maintenance	7,730
	OCM servicing & maintenance	2,210
	Envirologger servicing & maintenance	2,760
	Waste & garbage disposal	22,090
	BWTS servicing & maintenance	0
Sub-costs		**67,920**
Total		**437,310**
Total Operating Costs		**3,356,320**
Total operating costs ($ per day)		**9,200**
Total operating cost exc. dry docking		**2,921,740**
Total operating costs exc. dry docking ($ per day)		**8,000**

Figure 70. Indicative Operating Costs 2018 ($ Per Annum) of a Suezmax Vessel Part 2 / Source: Drewry Report 2018-2019

5.3.3 Acceptability

Considering that among the major defects of the ISM Code's implementation been found by multiple authors' investigations and interviews (see ISM Code & Safety Management System (SMS) section), are the heavy burden of bureaucracy, the complicated documentation, the lack of guidance and the non-uniform interpretation of the requirements, the acceptability of an upcoming process has to be proven when filtered from these parameters. In the case of the new process, the above limitations are examined in the below Table 10. Comparison of Usual Defects of the SMS processes and the Transformed Process's characteristics, where it is apparent that none of these defects have any form of application in the process.

Table 10. Comparison of Usual Defects of the SMS processes and the Transformed Process's characteristics

Usual Processes' Defects	Transformed Process
Bureaucracy Burden	No bureaucratical components, the process is fully automated and form filling procedure will be obliterated

Usual Processes’ Defects	Transformed Process
Complicated Documentation	No required documentation at all, fully automated and all wiring diagrams will be available onboard
Lack of Guidance	No guidance needed, only in case of malfunction of the automatic system
Non-Uniform Interpretation	No need for any interpretation of the form’s cell by any crew member, data collection is automated

Comparing to existing bureaucratical procedures, which exist and thrive within the industry, the suggested instrument seems to be a natural manifestation of the technological evolution, together with the crew’s desire, as all the required means are available and the only thing remaining is their adequate exploitation. The forecasted level of acceptance, by the seafarers’ community is high, since the only change which the new process will produce, is the relief of some workload. As for the office personnel, it is totally logical that a diligent and productive engineer, who monitors 5-7 vessels, would only require more and more data with an increasing rate of accuracy. Hence, the acceptability of the process is expected to be **high**, but it should be noted, only the results of the first implementation will show the actual adoption with confidence. At this stage, the transformed process achieved an overall score of 7.1/10, in terms of acceptability, on the survey.

5.3.4 Enforcement

Various investigations in the implementation of the ISM Code, such as Pun et al. (2002), discovered that among the most common and difficult problems faced, were lack of inter-departmental communication, insufficient knowledge of the procedures, low level education, frequent staff/crew turnover and the most important, time pressure to obtain registrations of the SMS. The combination of the above may lead to even worst problems and present huge holes in a company’s safety system. As for the suggested process, the automation is its key factor towards the confrontation of all the above, especially the time pressure issue along with the frequent staff/crew turnover.

Once the procedure has been effectively implemented and all required connections, modifications and restructures of the existing procedures have been in effect, there will be no need for training, familiarization or any similar process, as far as the Main Engine’s Performance Report is concerned. The practicality of the process’s implementation is almost exceptional, as no crew member will be affected, as well as any of the existing procedures. At the same time, it provides a considerable increase of good communication between the ship and the office, especially when it comes to technical problems troubleshooting, where all the relevant office’s engineers can be available at any time, observing live (depending on the refresh rate set by the company) the engine’s operation and potential failures, to provide the proper rectification, avoiding any unsafe working environment and potential risk for the environment.

As a result of the above, the enforcement of the suggested instrument is expected to be **efficient**, but the first results and feedback received by crew, will seal the effectiveness of its enforcement.

Even though, on the survey which took place within the company, the overall score of this criterion was the lowest of all, with 5.8/10.

5.3.5 Incentive and Innovation Effects

Continuous improvement is the basic principle of every forefront and vanguard quality management system, working together with the modern and state-of-the-art technology, always getting better and achieving improved efficiency, exceptional performance, greener emissions, more sophisticated environmental protection, together with the customer's satisfaction and higher quality operations. The new process embodies all the above, as it is an adaptive development with the use of the newest technologies and innovations, such as cutting-edge sensors, signal processing, data broadcast, live satellite communications, cloud and server storage and most importantly, data analytics and diagnostics.

Data Analytics is a subset of Data Science, which is described as an interdisciplinary field that uses multiple scientific methods, processes and algorithms to extract information and insights from structured, unstructured or totally raw and random data. Such techniques allow the analyst to observe trends and metrics that would otherwise be lost in the huge strings of information. Their outcome, can later be used to monitor the operation, identify failures, optimize processes and increase the overall efficiency of the system. The new process creates a continuous feed of information, which requires personnel with the adequate background to interpret it, thus, opens new jobs within the company.

Data science, combined with the artificial intelligence, machine learning and neural networks, which is a major trend in the shipping industry these days, can produce impressive predictions regarding the fuel oil consumptions at different loading conditions, varying fuels and constantly changing climate conditions, which is a major concern for both the owner (in case the vessel trades in the spot market) and the charterers (in case the vessel trades with a time-chartered contract). As far as the overall performance of the vessel is concerned, the live feed of data from the sensors, allows the management company to conduct speed trials and define the fouling condition of the hull and propeller.

As a consequence of the above, the transformed process can be perceived as highly innovative and with the allowance of great improvements, especially after the completion of the survey, which graded the transformed process in terms of innovation and incentive with a 8.4/10.

6 Conclusion

Lean Transformation methodology, addresses the existing processes with the scope to remove waste, obliterate what is possible and automate what is not, using innovative technology and high-quality standards. A company, in order to achieve the desired level of quality management, will need to constantly evaluate the existing procedures, while concurrently investing in new technologies which will allow it to remove completely others. The goal of every successful management system, is complete customization of the processes, based on the purpose, goals and standards of each company, avoiding at all costs the normalization within copying existing companies and buying 'off the shelves' generic standards.

Further to the evaluation of the process, which can only take place in a qualitative framework, including, inevitably with a substantial amount assumption, due to its nature. The need of a practical implementation is imperative, as any such process, which includes a long-term investment, in terms of either safety culture or performance optimization or efficiency increase, always within the allowance of the available sources, funds and means. Therefore, the overall acceptability and enforcement effectiveness of the process is left to be tested in action. It is necessary to note that no such process is static, as no process is perfect is terms of optimality, hence, continuous monitoring is essential for the proper maintenance of high-quality procedures within a company.

As it was mentioned in the survey, apart from the design of new processes and the transformation of existing ones, it is extremely important to always take measures for their effective implementation, considering the level of assimilation by the related parties. In other words, multiple personnel will need a relevant training in order to be able to work with new procedures, while other will need to 'get used to the new process' which may be a difficult transition for them. The team responsible for the implementation of the new processes, will need to take under consideration the wide spectrum of different characters and personalities within the company, avoiding the impose of the new processes without adequate familiarization. It is not unusual for innovative ideas, to fail in the beginning due to their fast-moving characteristics which cannot be effectively assimilated by the company's personnel.

The margin for improvement is big, both for the transformed process and the existing ones, therefore, the developed methodology is expected to be implemented in a wide range of manuals and procedures. At this point, it is important to note that in order for the ISM digitalization to be expanded in more and more automated forms and data, more funds need to be invested, in measuring instruments, sensors, gauges as well as other relevant facilitations, such as software, for the effective monitoring and control, logistics' systems, to address the stocks of the spares and other inventories.

The suggested methodology for the maintenance and continuous improvement of subject process is the agile project management, as described in the relevant section (Lean Transformation Using APM). Utilizing this methodology will allow the users to have multiple feedback loops with all related parties, including seafarers and office personnel, to share their experience of the process's functionality, while at the same time a culture of procedures' optimization will begin to spread within the company. Minor changes are more than welcome to the subject process, which will result in a fully customized and fit-for-purpose instrument, gradually fulfilling more and more of the users' requirements and expectations.

It is apparent that the digitalization of the quality management system is the trend of decade, integrating technology and automation. In the shipping industry, the number one priority shall be the decrease of the crew's workload, as the bureaucracy has expanded in unprecedented levels, transforming the Captains and the Chief Engineers to office personnel, instead of hand-on experts. The automatic receipt of the noon report is a goal which has to be set and achieved as soon as possible, considering that the required technology is already in place. Apart from the noon report, the complexity of the cargo, bunkering, transiting and other operations have prompted the office personnel to request an increasing quantity of paperwork.

Parallelly, in addition to this thesis and a potential future work on subject matter, would be the complete digitalization feasibility study, in terms of efficiency and applicability within the spectra of current technology. At the same time, all related research would require an adequate risk analysis, in terms of safety compromisations and electronic systems' reliability. The economic approach must also be examined, which comprises one of the least dealt matters when it comes to the International Safety Management and the safety in shipping industry in general. Lastly, two extremely important matters which need to be addressed concurrently when 'digitalizing' the ISM forms, is the sensors and gauges maintenance and calibration as well as the data filtration and cleansing.

The ultimate achievement of ISM's digitalization will be a central data processing and storage unit, to record everything that takes place onboard, along with all available sensors, gauges and inventories, which will allow the shore personnel to effectively monitor the vessel's operation, without compromising the safety of the crew, in terms of extended workload. With such a medium, the ISM data submission requirement will be fulfilled automatically through the system and all the needed alarms would have to be installed in the data monitoring software.

The high costs of automation and digitalization are only a tiny bit in front of those of a potential accident, both in monetary and social account, and such approach must be the standard practice of the evolved industry.

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8 Annex

8.1 Mapping

The mapping process of the Main Engine Performance Report - for MAN ME Engines (Form EO-173), is presented on Table 11. Mapping of ME Performance Report form and AMS Tags and the respective form is shown in Figure 71. Main Engine Performance Report 1/2 and Figure 72. Main Engine Performance Report 2/2

- **Description**: The respective value of the company's EO-173 form (Main Engine Performance Report) to be filled.
  Note:
  1. Rows with red shading, are data that will be removed, as they are either useless or not applicable/obsolete in the specific form due to modern engine design
  2. Rows with green shading, are data that the company is in discussions with sensor's makers in order to include the data output in the AMS.
- **EO-173 cell**: The respective cell of the EO-173 form, where the data, extracted from the AMS, will be presented.
- **AMS Tags/ Other:** The respective AMS tag which corresponds to the requested sensor/gauge's value.
  Note:
  1. LIB: static data taken directly from vessel's library (sea trials, model tests, manuals, drawings and plans)
  2. A-Z/0-9: alphanumeric values
  3. CODE: will be using company's ERP data input, along with AMS exports
  4. COMBINE: a combination of multiple AMS tags (e.g. Year, Month, Day, Hour, Seconds combined for DATE)
  5. FOBAS: Fuel Oil Bunker Analysis & Advisory Service results by Lloyd's Register
  6. PMI: Computer Controlled Surveillance – Engine Diagnostics System by MAN
- **Type/Unit:** The respective type of the data input and the relevant unit, if it has a physical meaning.
- **Count Y/N:** If YES, it means that the specific value has been successfully extracted from the AMS or a relevant library, if NO, either it was not possible as the sensor had no electronic output, or there was no sensor, or the company is in discussions with the maker to include this data in AMS.
- **Comments:** Various informative comments made on the mapping process.
- **Conv.**: Rows that are marked in this column, include values that need to be converted to the requested (by the form) unit, usually speeds (knots to m/s) and pressure (kg/cm^2 to bar).

Table 11. Mapping of ME Performance Report form and AMS Tags

Description	EO-173 cell	AMS Tag/ Other	Type / Unit	Count (Y/N)	Comments	Conv.
Engine Type	F7	LIB	A-Z/0-9	Y	S70MC-C (e.g.)	
Name of Vessel	K7	LIB	A-Z/0-9	Y	-	
Engine Builder	F9	LIB	A-Z/0-9	Y	-	
Engine No	K9	LIB	A-Z/0-9	Y	-	
Yard	O9	LIB	A-Z/0-9	Y	-	
Layout kW	D11	LIB	A-Z/0-9	Y	-	
Layout RPM	H11	ENGINE MCR	[rpm]	Y	-	
Engine Model	M11	LIB	A-Z/0-9	Y	-	
Signature	R11				TO BE REMOVED	
Test No.	X11	LIB	A-Z/0-9	Y	EIAPP Certificate Number	
No. of T/C	H15	LIB	A-Z/0-9	Y	-	
Maker	C17	LIB	A-Z/0-9	Y	-	
Type	G17	LIB	A-Z/0-9	Y	-	
Max. RPM	D19	LIB	[rpm]	Y	-	
Max. Temp	H19	LIB	[°C]	Y	-	
TC Specification	D23	LIB	A-Z/0-9	Y	-	
Serial No. TC 1	M16	LIB	A-Z/0-9	Y	-	
Serial No. TC 2	M18	LIB	A-Z/0-9	Y	-	
No. of Cylinders	Q15	LIB	[#]	Y	-	
Bore	T15	LIB	[m]	Y	-	
Stroke	X15	LIB	[m]	Y	-	
Cylinder Constant	S17	LIB	[kW, bar]	Y	-	
Mean Friction Pressure	X17	LIB	[bar]	Y	-	
Internal	Q21	LIB	[X]	Y	if "Internal" fill 'X'	
External from ME System	U21	LIB	[X]	Y	if "External from ME" fill 'X'	
External from Gravity Tank	Y21	LIB	[X]	Y	if "External from Gravity Tank" fill 'X'	
Observation No.	E25	FOBAS	[#]	Y	Fuel Oil Analysis Results	
Fuel Oil Viscosity	E27	ME178	[cSt]	Y	-	

Description	EO-173 cell	AMS Tag/ Other	Type / Unit	Count (Y/N)	Comments	Conv.
Fuel Oil Temperature	I27	FOB006	[°C]	Y	-	
Bunker Station	D29	CODE	A-Z/0-9	Y	Fuel Oil Analysis Results	
Oil Brand	D31	CODE	A-Z/0-9	Y	Fuel Oil Analysis Results	
Heat value	K31	CODE	[#]	Y	Fuel Oil Analysis Results	
Density at 15°C	E33	FOB010	[kg/m3]	Y	Flowing Density	
Sulphur	K33	CODE	[%]	Y	Fuel Oil Analysis Results	
Cylinder Oil Brand	R29	N/A	A-Z/0-9	N	Manual entry	
Cylinder Oil Type/TBN	V29	N/A	A-Z/0-9	N	Manual entry	
Circulating Oil Brand	R21	N/A	A-Z/0-9	N	Manual entry	
Circulating Oil Type/TBN	V31	N/A	A-Z/0-9	N	Manual entry	
Turbo Oil Brand	R33	N/A	A-Z/0-9	N	Manual entry	
Turbo Oil Type/TBN	V33	N/A	A-Z/0-9	N	Manual entry	
Test Date (yyyy-mm-dd)	B38	COMBINE	[date]	Y	-	
UTC Year	-	NAV_IN_04	[#]		COMBINE	
UTC Month	-	NAV_IN_05	[#]		COMBINE	
UTC Day	-	NAV_IN_06	[#]		COMBINE	
Test Hour (hh:mm)	D38	COMBINE	[time]	Y	-	
UTC Hour	-	NAV_IN_01	[#]		COMBINE	
UTC Minutes	-	NAV_IN_02	[#]		COMBINE	
Effective Power	B42	SPM03	[kW]	Y	*shaft efficiency check shop test	
Effective Fuel Consumption	F42	FUEL_EFF	[g/kWh]	Y	ME FUEL EFF CORR	
Indicated Fuel Consumption	I42	SPM08	[g/kWh]	Y	ME SFR	
Engine RPM	M38	ME RPM	[rpm]	Y	-	
Total Running Hours	P38	HOUR COUNTER	[h]	Y	-	
Governor Index	S38				TO BE REMOVED (no governor index)	
Speed Setting RPM	V38	SPEED S BR	[rpm]	Y	Speed set from Bridge	
VIT Control bar	X38				TO BE REMOVED (no VIT control bar)	
Draft Fore	P40	BT015.SYS	[m]	Y	-	
Draft Aft.	P42	BT018.SYS	[m]	Y	-	
Log Knots	S40	NAV_IN_09	[kn]	Y	Ground Speed GPS	

Description	EO-173 cell	AMS Tag/ Other	Type / Unit	Count (Y/N)	Comments	Conv.
Observed Knots	S42	NAV_IN_23	[kn]	Y	Water Speed Long	
Wind Speed	U40	NAV_IN_18	[kn]	Y	Relative, should be converted to m/s	***
Wind Direction	X40	NAV_IN_17	[°]	Y	Relative	
Wave Height	U42	N/A	[m]	N	Manual entry / Observation needed	
Wave Direction	X42	N/A	[°]	N	Manual entry / Observation needed	
Indicative Pressure Cyl. 1	G45	PMI	[bar]	N	Engine Diagnostics System	***
Indicative Pressure Cyl. 2	H45	PMI	[bar]	N	Engine Diagnostics System	***
Indicative Pressure Cyl. 3	I45	PMI	[bar]	N	Engine Diagnostics System	***
Indicative Pressure Cyl. 4	J45	PMI	[bar]	N	Engine Diagnostics System	***
Indicative Pressure Cyl. 5	K45	PMI	[bar]	N	Engine Diagnostics System	***
Indicative Pressure Cyl. 6	L45	PMI	[bar]	N	Engine Diagnostics System	***
Max. Pressure Cyl. 1	G46	PMI	[bar]	N	Engine Diagnostics System	***
Max. Pressure Cyl. 2	H46	PMI	[bar]	N	Engine Diagnostics System	***
Max. Pressure Cyl. 3	I46	PMI	[bar]	N	Engine Diagnostics System	***
Max. Pressure Cyl. 4	J46	PMI	[bar]	N	Engine Diagnostics System	***
Max. Pressure Cyl. 5	K46	PMI	[bar]	N	Engine Diagnostics System	***
Max. Pressure Cyl. 6	L46	PMI	[bar]	N	Engine Diagnostics System	***
Ref. Max. Pressure Cyl. 1	G47	LIB	[bar]	Y	as per Shop Test	***
Ref. Max. Pressure Cyl. 2	H47	LIB	[bar]	Y	as per Shop Test	***
Ref. Max. Pressure Cyl. 3	I47	LIB	[bar]	Y	as per Shop Test	***
Ref. Max. Pressure Cyl. 4	J47	LIB	[bar]	Y	as per Shop Test	***
Ref. Max. Pressure Cyl. 5	K47	LIB	[bar]	Y	as per Shop Test	***
Ref. Max. Pressure Cyl. 6	L47	LIB	[bar]	Y	as per Shop Test	***
Compression Pressure Cyl. 1	G48	PMI	[bar]	N	Engine Diagnostics System	***
Compression Pressure Cyl. 2	H48	PMI	[bar]	N	Engine Diagnostics System	***
Compression Pressure Cyl. 3	I48	PMI	[bar]	N	Engine Diagnostics System	***
Compression Pressure Cyl. 4	J48	PMI	[bar]	N	Engine Diagnostics System	***
Compression Pressure Cyl. 5	K48	PMI	[bar]	N	Engine Diagnostics System	***
Compression Pressure Cyl. 6	L48	PMI	[bar]	N	Engine Diagnostics System	***
Fuel Index Offset High Load Cyl.1	G49	PMI	[#]	N	Engine Diagnostics System	

Description	EO-173 cell	AMS Tag/ Other	Type / Unit	Count (Y/N)	Comments	Conv.
Fuel Index Offset High Load Cyl.2	H49	PMI	[#]	N	Engine Diagnostics System	
Fuel Index Offset High Load Cyl.3	I49	PMI	[#]	N	Engine Diagnostics System	
Fuel Index Offset High Load Cyl.4	J49	PMI	[#]	N	Engine Diagnostics System	
Fuel Index Offset High Load Cyl.5	K49	PMI	[#]	N	Engine Diagnostics System	
Fuel Index Offset High Load Cyl.6	L49	PMI	[#]	N	Engine Diagnostics System	
Fuel Index Offset Low Load Cyl.1	G50	PMI	[#]	N	Engine Diagnostics System	
Fuel Index Offset Low Load Cyl.2	H50	PMI	[#]	N	Engine Diagnostics System	
Fuel Index Offset Low Load Cyl.3	I50	PMI	[#]	N	Engine Diagnostics System	
Fuel Index Offset Low Load Cyl.4	J50	PMI	[#]	N	Engine Diagnostics System	
Fuel Index Offset Low Load Cyl.5	K50	PMI	[#]	N	Engine Diagnostics System	
Fuel Index Offset Low Load Cyl.6	L50	PMI	[#]	N	Engine Diagnostics System	
Max. Pressure Adjustment Cyl. 1	G51	PMI	[bar]	N	Engine Diagnostics System	***
Max. Pressure Adjustment Cyl. 2	H51	PMI	[bar]	N	Engine Diagnostics System	***
Max. Pressure Adjustment Cyl. 3	I51	PMI	[bar]	N	Engine Diagnostics System	***
Max. Pressure Adjustment Cyl. 4	J51	PMI	[bar]	N	Engine Diagnostics System	***
Max. Pressure Adjustment Cyl. 5	K51	PMI	[bar]	N	Engine Diagnostics System	***
Max. Pressure Adjustment Cyl. 6	L51	PMI	[bar]	N	Engine Diagnostics System	***
Compression Ratio (Pcomp/Pscav) Cyl. 1	G52	PMI	[#]	N	Engine Diagnostics System	
Compression Ratio (Pcomp/Pscav) Cyl. 2	H52	PMI	[#]	N	Engine Diagnostics System	
Compression Ratio (Pcomp/Pscav) Cyl. 3	I52	PMI	[#]	N	Engine Diagnostics System	
Compression Ratio (Pcomp/Pscav) Cyl. 4	J52	PMI	[#]	N	Engine Diagnostics System	
Compression Ratio (Pcomp/Pscav) Cyl. 5	K52	PMI	[#]	N	Engine Diagnostics System	
Compression Ratio (Pcomp/Pscav) Cyl. 6	L52	PMI	[#]	N	Engine Diagnostics System	
Exhaust Valve Open Timing Cyl. 1	G53	PMI	[°]	N	Engine Diagnostics System	
Exhaust Valve Open Timing Cyl. 2	H53	PMI	[°]	N	Engine Diagnostics System	
Exhaust Valve Open Timing Cyl. 3	I53	PMI	[°]	N	Engine Diagnostics System	
Exhaust Valve Open Timing Cyl. 4	J53	PMI	[°]	N	Engine Diagnostics System	
Exhaust Valve Open Timing Cyl. 5	K53	PMI	[°]	N	Engine Diagnostics System	
Exhaust Valve Open Timing Cyl. 6	L53	PMI	[°]	N	Engine Diagnostics System	
Exhaust Gas Temperature Cyl. 1	G54	ME101	[°C]	Y	M/E No 1 Cyl. Exh gas Aft Exh V/V	

Description	EO-173 cell	AMS Tag/ Other	Type / Unit	Count (Y/N)	Comments	Conv.
Exhaust Gas Temperature Cyl. 2	H54	ME102	[°C]	Y	M/E No 2 Cyl. Exh gas Aft Exh V/V	
Exhaust Gas Temperature Cyl. 3	I54	ME103	[°C]	Y	M/E No 3 Cyl. Exh gas Aft Exh V/V	
Exhaust Gas Temperature Cyl. 4	J54	ME104	[°C]	Y	M/E No 4 Cyl. Exh gas Aft Exh V/V	
Exhaust Gas Temperature Cyl. 5	K54	ME105	[°C]	Y	M/E No 5 Cyl. Exh gas Aft Exh V/V	
Exhaust Gas Temperature Cyl. 6	L54	ME106	[°C]	Y	M/E No 6 Cyl. Exh gas Aft Exh V/V	
Cooling Water Outlet Temp. Cyl. 1	G55	ME127	[°C]	Y	M/E NO.1 J.C.F.W OUTLET TEMP. H	
Cooling Water Outlet Temp. Cyl. 2	H55	ME128	[°C]	Y	M/E NO.2 J.C.F.W OUTLET TEMP. H	
Cooling Water Outlet Temp. Cyl. 3	I55	ME129	[°C]	Y	M/E NO.3 J.C.F.W OUTLET TEMP. H	
Cooling Water Outlet Temp. Cyl. 4	J55	ME130	[°C]	Y	M/E NO.4 J.C.F.W OUTLET TEMP. H	
Cooling Water Outlet Temp. Cyl. 5	K55	ME131	[°C]	Y	M/E NO.5 J.C.F.W OUTLET TEMP. H	
Cooling Water Outlet Temp. Cyl. 6	L55	ME132	[°C]	Y	M/E NO.6 J.C.F.W OUTLET TEMP. H	
Piston Cooling Lub. Temp. Cyl. 1	G56	ME143	[°C]	Y	M/E NO.1 P.C.O OUTLET TEMP HIGH	
Piston Cooling Lub. Temp. Cyl. 2	H56	ME144	[°C]	Y	M/E NO.2 P.C.O OUTLET TEMP HIGH	
Piston Cooling Lub. Temp. Cyl. 3	I56	ME145	[°C]	Y	M/E NO.3 P.C.O OUTLET TEMP HIGH	
Piston Cooling Lub. Temp. Cyl. 4	J56	ME146	[°C]	Y	M/E NO.4 P.C.O OUTLET TEMP HIGH	
Piston Cooling Lub. Temp. Cyl. 5	K56	ME147	[°C]	Y	M/E NO.5 P.C.O OUTLET TEMP HIGH	
Piston Cooling Lub. Temp. Cyl. 6	L56	ME148	[°C]	Y	M/E NO.6 P.C.O OUTLET TEMP HIGH	
A/C 1 Inlet Water Temp.	B67	ME126	[°C]	Y	M/E A/C C.W INLET TEMP. HIGH	
A/C 1 Outlet Water Temp.	C67	ME221	[°C]	Y	M/E NO.1 AIR COOL.C.F.W OUT.TEMP	
A/C 2 Inlet Water Temp.	B69	ME126	[°C]	Y	M/E A/C C.W INLET TEMP. HIGH	
A/C 2 Outlet Water Temp.	C69	ME222	[°C]	Y	M/E NO.2 AIR COOL.C.F.W OUT.TEMP	
ME Cool. Water Inlet Temp.	D66	ME142.1	[°C]	Y	M/E J.C.W INLET TEMP.HIGH/LOW	
Sea Water Temp.	D69	IM024	[°C]	Y	MAIN C.S.W P/P INLET TEMP	
ME T/C 1 Cool. Water Outlet Temp.	E67	N/A	[°C]	N	-	
ME T/C 2 Cool. Water Outlet Temp.	E69	N/A	[°C]	N	-	
T/C 1 Exh. Gas Inlet Temp.	G67	ME109	[°C]	Y	M/E NO.1 T/C EXH GAS INLET TEMP	
T/C 1 Exh. Gas Outlet Temp.	I67	ME107	[°C]	Y	M/E NO.1 T/C EXH GAS OUTLET TEMP	
T/C 2 Exh. Gas Inlet Temp.	G69	ME110	[°C]	Y	M/E NO.2 T/C EXH GAS INLET TEMP	
T/C 2 Exh. Gas Outlet Temp.	I69	ME108	[°C]	Y	M/E NO.2 T/C EXH GAS OUTLET TEMP	
Inlet Blower A/C 1	D80	ME120	[°C]	Y	M/E SCAV. AIR RECEIVER TEMP. H	

Description	EO-173 cell	AMS Tag/ Other	Type / Unit	Count (Y/N)	Comments	Conv.
Inlet Blower A/C 2	D82	ME120	[°C]	Y	M/E SCAV. AIR RECEIVER TEMP. H	
Before A/C 1	F80	ME229	[°C]	Y	M/E SCAV.AIR TEMP AIR COOL1	
After A/C 1	I80	ME227	[°C]	Y	M/E AIR OUTLET NO.1 AIR COOL.	
Before A/C 2	F82	ME230	[°C]	Y	M/E SCAV.AIR TEMP AIR COOL2	
After A/C 2	I82	ME228	[°C]	Y	M/E AIR OUTLET NO.2 AIR COOL.	
Receiver (bar)	L66	ME138	[kg/cm2]	Y	M/E SCAV.AIR RECEIVER PRESS ___ to bar	***
T/C 1 Outlet	N67	N/A	[mmWC]	N	-	
T/C 2 Outlet	N69	N/A	[mmWC]	N	-	
T/C 1 RPM (X10)	P67	ME164	[rpm]	Y	M/E NO.1 T/C RPM HIGH(X10)	
T/C 2 RPM (X10)	P69	ME165	[rpm]	Y	M/E NO.2 T/C RPM HIGH(X10)	
Aux. Blowers On/Off	R66	N/A	[0/1]	N	Manual entry	
Axial Vibration	R70	SLD 24	A-Z/0-9	Y	Checks only that values are within limits	
ΔP Filter	T67	N/A	[mmWC]	N	Manual entry	
ΔP Cooler	V67	N/A	[mmWC]	N	Manual entry	
Receiver (bar)	X66	ME138	[kg/cm2]	Y	M/E SCAV.AIR RECEIVER PRESS __ to bar	***
System Oil Press. (bar)	L80	ME156	[kg/cm2]	Y	M/E L.O INLET PRESS.LOW	***
Cooling Oil Press. (bar)	L82	N/A	[kg/cm2]	N	-	***
Turbine Oil Press. (bar)	L84	ME122/123	[kg/cm2]	Y	M/E L.O INLET NO.1 & 2 T/C PRESS	***
Inlet Engine Temp.	L87	ME133	[°C]	Y	M/E L.O INLET TEMP. HIGH/LOW	
Thrust Segment Temp.	L89	ME155	[°C]	Y	M/E THRUST BEARING SEG. TEMP H	
T/C 1 Inlet or Blower End Temp.	O82	N/A	[°C]	N	-	
T/C 1 Outlet or Turb. End Temp.	Q82	ME117	[°C]	Y	M/E NO.1 T/C L.O OUTLET TEMP. H	
T/C 2 Inlet or Blower End Temp.	O84	N/A	[°C]	N	-	
T/C 2 Outlet or Turb. End Temp.	Q84	ME118	[°C]	Y	M/E NO.2 T/C L.O OUTLET TEMP. H	
Press. Before Filter (bar)	S80	N/A	[kg/cm2]			***
Press. After Filter (bar)	S82	ME135	[kg/cm2]	Y	M/E F.O INLET PRESS.LOW	
Temp. Before Pumps	S85	CODE	[°C]	Y	Choose respective TK based on Inj. Temp	
HFO Service Tank Temp.	-	IM022	[°C]		H.F.O SERV. TK TEMP. HIGH	
LSHFO Service Tank Temp.	-	IM025	[°C]		L.S H.F.O SERV. TK TEMP. HIGH	
MGO Service Tank Temp.	-	IM031	[°C]		M.G.O SERV. TK TEMP. HIGH	

Description	EO-173 cell	AMS Tag/ Other	Type / Unit	Count (Y/N)	Comments	Conv.
Press. Before Filter (bar)	V80	N/A	[kg/cm2]	N	-	***
Press. After Filter (bar)	V82	N/A	[kg/cm2]	N	-	***
Main Pressure (bar)	V84	HP015	[kg/cm2]	Y	HPU PRESS.INDICATION	***
Position 1	V87	N/A	[%]	N	-	
Position 2	X87	N/A	[%]	N	-	

Service Data (ME)

Engine Type: Name of vessel:
Engine Builder: Engine No.: Yard:
Layout kW: Layout RPM: Engine Mode: Sign.: Test No.:

Turbocharger(s)

No. of TC:
Make: Type:
Max. RPM: Max. Temp., °C:
Compr. Slip Factor: Compr. Diam., m:
TC specification:

Serial No.	
1	
2	
3	
4	

No. of Cyl.: Bore, m: Stroke, m:
Cylinder Constant (kW,bar): Mean Friction. Press., bar:

Lubrication Oil System (Tick box)

Internal | External from M.E. System | External from Gravity Tank

Observation No:
Fuel Oil Viscosity: at: °C
Bunker Station:
Oil Brand: Heat value, kcal/kg:
Density at 15 °C: Sulphur, %:

	Brand	Type/TBN
Cylinder Oil		
Circulating Oil		
Turbo Oil		

Test Date (yyyy-mm-dd)	Test Hour (hh:mm)	Load %	Ambient Pressure mbar	Engine RPM	Total Running Hours	Governor index	Speed Setting RPM	VIT Control bar

Effective Power kW	Indicated Power kW	Eff. Fuel Consumption g/kWh	Indicated Fuel Consumption g/kWh

Draft Fore, m	Log Knots	Wind, m/s	Direction, °
Draft Aft, m	**Obs. Knots**	**Wave Height, m**	**Direction, °**

Cylinder No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Ave.
Pi, bar																			
Pmax, bar																			
Ref. Pmax, bar																			
Pcomp, bar																			
Fuel Index Offset, HIGH Load																			
Fuel Index Offset, LOW Load																			
Pmax Adjustment, bar																			
Pcomp Ratio (Pcomp/Pscav)																			
Exh. Valve Open Timing, °CA																			
Exhaust Gas Temp., °C																			
Cooling Water Outlet Temp., °C																			
Piston Outlet Lub. Temp., °C																			

NOT TO BE TESTED LESS THAN 75% LOAD

Figure 71. Main Engine Performance Report 1/2

Tsakos Columbia Shipmanagement ("TCM") S.A.

Shipboard Engine Room Operations Manual (SEROM)

EO-173: Main Engine Performance Report - For MAN ME Engines

Cooling Water Temperature, °C				Exhaust Gas Temp., °C	
Air Cooler		Main Engine		Turbine	
Inlet	Outlet	Inlet	Turb. Outlet	Inlet	Outlet
1	**1**		**1**	**1**	**1**
		Seaw. Temp.			
2	**2**		**2**	**2**	**2**
3	**3**		**3**	**3**	**3**
4	**4**		**4**	**4**	**4**
Ave.	**Ave.**		**Ave.**	**Ave.**	**Ave.**

Exhaust Pressure		Turbo Charger RPM	Aux. Blower	Scavenge Air Pressure		
Receiver	Turb. Outl.			▲p Filter mmWc	▲p Cooler mmWc	Receiver
bar	mmWC		On/Off			bar
	1	**1**		**1**	**1**	
mmHg			Axial Vibration mm			mmHg
	2	**2**		**2**	**2**	
	3	**3**		**3**	**3**	
	4	**4**		**4**	**4**	
	Ave.	**Ave.**		**Ave.**	**Ave.**	

Scavenge Air Temperature, °C			
Scavenge Air Temperature	Inlet Blower	Before Cooler	After Cooler
	1	**1**	**1**
	2	**2**	**2**
	3	**3**	**3**
	4	**4**	**4**
	Ave.	**Ave.**	**Ave.**

Lubricating Oil		
Pressure, bar	Temperature, °C	
System Oil	TC Inlet / Blower end	TC Outlet / Turb. End
Cooling Oil	**1**	**1**
Turbine Oil	**2**	**2**
Temperature, °C	**3**	**3**
Inlet Engine		
	4	**4**
Thrust Segment		
	Ave.	**Ave.**

Fuel Oil Pressure, bar
Before Filter
After Filter
Temperature, °C
Before Pumps

Hydraulic Pressure, bar	
Before Filter	
After Filter	
Main Pressure	
Swash Plate Position, %	
1	2
3	4

Remarks:	

NOT TO BE TESTED LESS THAN 75% LOAD

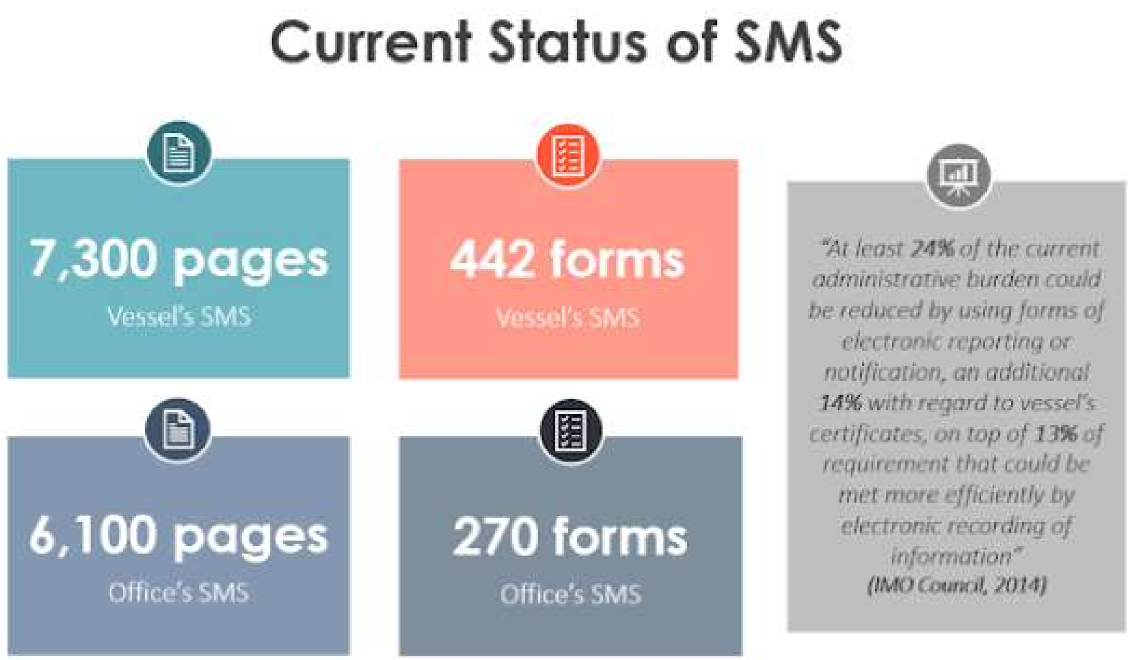
Figure 72. Main Engine Performance Report 2/2

8.2 Questionnaire

ISM Digitalization Questionnaire

A brief survey, to be conducted within TCM, to evaluate the effects of ISM Digitalization and specifically the partial automation of the SEROM form "EO-173 Main Engine Performance Report - For MAN ME Engines"

*Required



Do you believe that ISM Digitalization is an effective method to reduce the crew's workload? *

- ○ Yes
- ○ No
- ○ Maybe

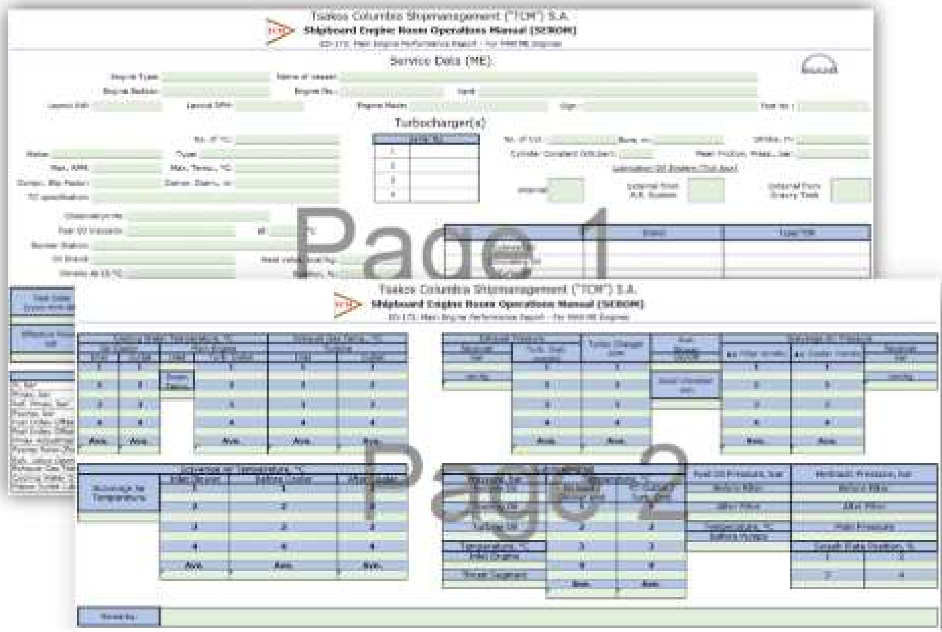
Where we are now!

Existing Process

The implementation of the 'Lean Transformation' took place on the **Main Engine's Performance Report Form**, which is currently manual-matic. The aim was to automatically complete as many cells as possible, with **no additional funds and sources** used.

Form's Cells:

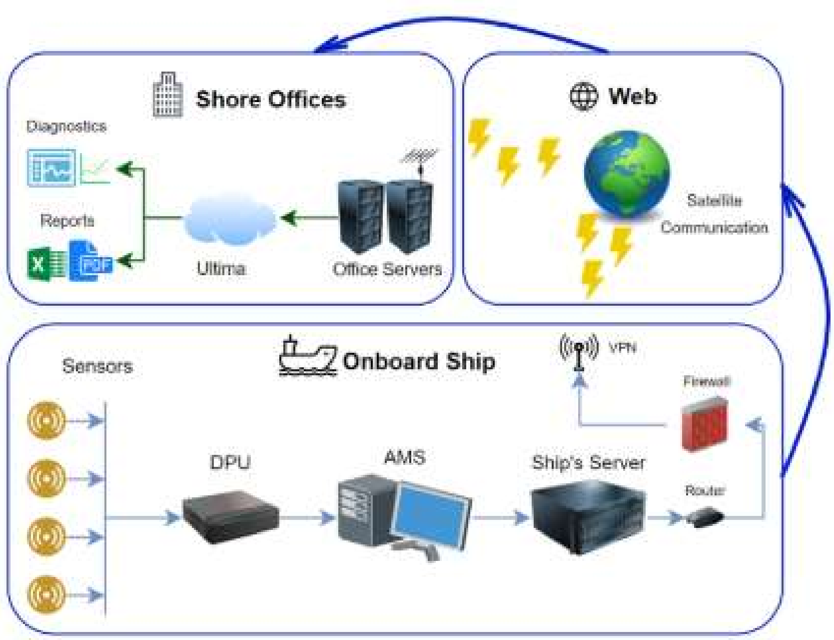
177



Where we aim to be!

Transformed Process

The transformed process directs the data from the sensors, to the DPU for signal-distribution, then to the AMS for signal-processing, to the server for recording and then through the satellite services directly to the company's servers & ERP (Ultima) for automatic reporting (form filling), analysis and diagnostics.



What we achieved with the iAMS export! (integrated Alarm & Monitoring System)

Main Engine Performance Report - for MAN ME Engines

Description	Form's Cell	AMS Tag	Type or Unit	Comments
T/C 1 RPM (X10)	P67	ME164	[rpm]	M/E NO.1 T/C RPM HIGH(X10)
T/C 2 RPM (X10)	P69	ME165	[rpm]	M/E NO.2 T/C RPM HIGH(X10)
Receiver (bar)	X66	ME138	[kg/cm2]	M/E SCAV.AIR RECEIVER PRESS __ to bar
System Oil Press. (bar)	L80	ME156	[kg/cm2]	M/E L.O INLET PRESS.LOW
Turbine Oil Press. (bar)	L84	ME122/123	[kg/cm2]	M/E L.O INLET NO.1 & 2 T/C PRESS
Press. After Filter (bar)	S82	ME133	[kg/cm2]	M/E F.O INLET PRESS LOW
Exhaust Gas Temperature Cyl. 1	G54	ME101	[°C]	M/E No 1 Cyl. Exh gas Aft Exh V/V
Exhaust Gas Temperature Cyl. 2	H54	ME102	[°C]	M/E No 2 Cyl. Exh gas Aft Exh V/V
Exhaust Gas Temperature Cyl. 3	I54	ME103	[°C]	M/E No 3 Cyl. Exh gas Aft Exh V/V
Exhaust Gas Temperature Cyl. 4	J54	ME104	[°C]	M/E No 4 Cyl. Exh gas Aft Exh V/V
Exhaust Gas Temperature Cyl. 5	K54	ME105	[°C]	M/E No 5 Cyl. Exh gas Aft Exh V/V
Exhaust Gas Temperature Cyl. 6	L54	ME106	[°C]	M/E No 6 Cyl. Exh gas Aft Exh V/V
Cooling Water Outlet Temp. Cyl. 1	G55	ME127	[°C]	M/E NO.1 J.C.F.W OUTLET TEMP. H
Cooling Water Outlet Temp. Cyl. 2	H55	ME128	[°C]	M/E NO.2 J.C.F.W OUTLET TEMP. H
Cooling Water Outlet Temp. Cyl. 3	I55	ME129	[°C]	M/E NO.3 J.C.F.W OUTLET TEMP. H
Cooling Water Outlet Temp. Cyl. 4	J55	ME130	[°C]	M/E NO.4 J.C.F.W OUTLET TEMP. H
Cooling Water Outlet Temp. Cyl. 5	K55	ME131	[°C]	M/E NO.5 J.C.F.W OUTLET TEMP. H
Cooling Water Outlet Temp. Cyl. 6	L55	ME132	[°C]	M/E NO.6 J.C.F.W OUTLET TEMP. H
Piston Cooling Lub. Temp. Cyl. 1	G56	ME143	[°C]	M/E NO.1 P.C.O OUTLET TEMP HIGH
Piston Cooling Lub. Temp. Cyl. 2	H56	ME144	[°C]	M/E NO.2 P.C.O OUTLET TEMP HIGH
Piston Cooling Lub. Temp. Cyl. 3	I56	ME145	[°C]	M/E NO.3 P.C.O OUTLET TEMP HIGH
Piston Cooling Lub. Temp. Cyl. 4	J56	ME146	[°C]	M/E NO.4 P.C.O OUTLET TEMP HIGH
Piston Cooling Lub. Temp. Cyl. 5	K56	ME147	[°C]	M/E NO.5 P.C.O OUTLET TEMP HIGH
Piston Cooling Lub. Temp. Cyl. 6	L56	ME148	[°C]	M/E NO.6 P.C.O OUTLET TEMP HIGH
A/C 1 Inlet Water Temp.	B67	ME126	[°C]	M/E A/C C.W INLET TEMP. HIGH
A/C 1 Outlet Water Temp.	C67	ME221	[°C]	M/E NO.1 AIR COOL C.F.W OUT TEMP
A/C 2 Inlet Water Temp.	B69	ME126	[°C]	M/E A/C C.W INLET TEMP. HIGH
A/C 2 Outlet Water Temp.	C69	ME222	[°C]	M/E NO.2 AIR COOL C.F.W OUT TEMP
ME Cool. Water Inlet Temp.	D66	ME142.1	[°C]	M/E J.C.W INLET TEMP.HIGH/LOW
Sea Water Temp.	D69	IM024	[°C]	MAIN C.S.W P/P INLET TEMP

How effective is this method to minimize the time lost in data collection? *

	1	2	3	4	5	
Ineffective	○	○	○	○	○	Successful

How appropriate/fit-for-purpose is the method? *

	1	2	3	4	5	
Not appropriate	○	○	○	○	○	Highly appropriate

How would you assess the economic benefits of the system, with respect to the human error minimization and crew's workload reduction? *

	1	2	3	4	5	
Not efficient	○	○	○	○	○	Highly efficient

How accepted/easily adopted will the digital ISM be, by the stakeholders? (Crew, Technical & Marine Superintendents etc.) *

	1	2	3	4	5	
Rejected	○	○	○	○	○	Fully Accepted

How effectively will this system be implemented and overcome potential barriers? *

	1	2	3	4	5	
Difficult	○	○	○	○	○	Easy

Does this system encourage and motivate related parties to perform better, promoting their contribution? *

	1	2	3	4	5	
Not at all	○	○	○	○	○	Very much

Does this system enhance the innovative thinking of the company, compared to the current industry standards? *

	1	2	3	4	5	
Not at all	○	○	○	○	○	Very much

Which is your age group? *

- ○ 18-24
- ○ 25-34
- ○ 35-44
- ○ 45-54
- ○ Over 55

What is your gender?

- ○ Male
- ○ Female
- ○ Other: ____________

What is the highest degree or level of school you have completed? *

- ○ High school degree or equivalent
- ○ Bachelor's degree
- ○ Master's Degree
- ○ Doctorate
- ○ Other: ______________________