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Ensuring the effective implementation of the monitoring, reporting and verification (MRV) system in shipping: a step towards making energy-efficiency happen

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ENSURING THE EFFECTIVE IMPLEMENTATION OF THE MONITORING, REPORTING AND VERIFICATION (MRV) SYSTEM IN SHIPPING: A STEP TOWARDS MAKING ENERGY-EFFICIENCY HAPPEN

By

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DISSERTATION DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

(Signature): ....

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ABSTRACT

Title of Dissertation:

Ensuring the Effective Implementation of the Monitoring, Reporting and Verification (MRV) System in Shipping: A Step Towards Making Energy-Efficiency Happen

Degree: **Master of Science in Maritime Affairs**

Monitoring, Reporting and Verification (MRV) is an important element for the assessment of GHG emissions. It is necessary to understand the maritime industry's standpoint and future trend of a GHG emissions scenario to facilitate regulatory developments in regional and global level. MRV is mandatory for ships of specific sizes under IMO (from 1 January 2019) and EU (from 1 January, 2018). Measurement of emissions from maritime transport is also crucial to initiate stricter control and development of the new regulatory regime, as shipping emissions in a Business-As-Usual Scenario will increase between 50% to 250% by 2050. The research presented herein investigates the gaps and barriers for implementing the MRV onboard vessels. Vessel's existing data collection regime and data collected were studied via an online survey. Different perspectives on gaps and barriers to the MRV were analyzed such as administrative, technological, human elements and data quality. This research employs the Multiple Attribute Decision Making (MADM) tool (Technique for Order of Preference to Ideal Solution-TOPSIS) for selecting the best applicable fuel consumption monitoring method which potentially facilitate the implementation process of the MRV and maintenance of data accuracy and robustness. The holistic and enhanced understanding on gaps, barriers and use of appropriate data collection method will help policymakers to adopt better strategic decisions for energy efficiency enhancement and smooth implementation of a MRV system in the IMO and EU.

Keywords: Shipping Emissions, MRV, Data Collection System, and Data quality.

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LIST OF ABBREVIATIONS

ARP	Acid Rain Program
BAU	Business-As-Usual
BDN	Bunker Delivery Note
CAPEX	Capital Expenditure
CDM	Clean Development Mechanism
CELA	Chief Engineer’s Log Abstract
CMMS	Computerized Maintenance Management System
COP21	Conference of Parties 21
CO2	Carbon Dioxide
COQ	Certificate of Quality
DCS	Data Collection System
DCP	Data Collection Plan
DF	Distillate FAME
DQM	Data Quality Management
EEDI	Energy efficiency Design Index
EEOI	Energy efficiency Operational Index
EPA	Environment Protection Agency
EU	European Union
EU-ETS	European Union Emission Trading Scheme
EU-MRV	European Union-Monitoring, Reporting and Verification
FAO	Food and Agricultural Organization
FC	Fuel Consumption
FCDCS	Fuel Consumption Data Collection System
FO	Fuel Oil
GHG	Green House Gas
IMO	International Maritime Organization

IMO-DCS	International Maritime Organization- Data Collection System
INDC’s	Intended Nationally Determined Contributions
IPCC	International Panel for Climate Change
ISM CODE	International Safety Management CODE
ISO	International Standardization Organization
JI	Joint Implementation
LEDS	Low-Emission Development Strategies
MARPOL	Marine Pollution
MADM	Multi Attribute Decision Making
MBM	Market-Based-Measures
MEPC	Marine Environment Protection Committee
MP	Monitoring Plan
MRV	Monitoring, Reporting and Verification
NAMAs	Nationally Appropriate Mitigation Actions
NBTP	Nox Budget Trading Program
NDCs	Nationally Determined Contributions
NOx	Nitrogen Oxides
OPEX	Operating Expenditure
O&M	Operational and Maintenance
REDD+	Reducing Emissions from Deforestation and Forest Degradation+
RO	Recognized Organization
SEEMP	Shipboard Energy Efficiency Management Plan
SO_2	Sulphur Oxides
SOC	Statement of Compliance
TOPSIS	Technique for Order of Preference to Ideal Solution
UN	United Nations
UNFCCC	United Nation Framework Convention for Climate Change
UNDP	United Nations Development Program

Chapter I

Introduction

1.1 Background

Climate change has discernible effect on earth ecosystem and threat to human existence. Recent studies on climate systems suggests that human elements are the cause for the climate anomaly (IPCC, 2013). The continued emission is causing irreversible change in the climate system, and the change in global and regional climate is more significant than ever before. The IPCC fourth assessment report (AR4) stated that 1983-2012 was the warmest 30-year period in the last 1400 years. The magnitude of the damage can only be minimized by stricter control over Greenhouse Gas (GHG) emissions globally. Realizing the adverse impact, global communities have initiated actions to achieve stricter control over GHG emissions and have established policies under the United Nations (UN) and International Maritime Organization (IMO) to retain the world's existence for future generations. However, shipping and aviation industry have been excluded from the Paris Agreement, because of their international nature and being controlled by specialized body of UN (IPCC, 2013).

The emission from the maritime industry is approximately 2.8% of the global annual total GHG emission. In a Business-As-Usual (BAU) scenario the shipping emission will increase between 50% to 250% by 2050 (IMO, 2015). According to STATISTA, there are more than 51,400 merchant ships (as of 1 January, 2016) are sailing around the world, which are responsible for consuming an average 350 million tons of fuel oil per year. The IMO Third GHG study, in 2014, suggested that the shipping industry is responsible for emitting about 938 million tons of CO_2 and 961 million tons of CO_2e in the year 2012; this constitutes 2.1-2.2% of the world total emission. About 75% of the emission from shipping can be reduced by the operational measures and availing existing energy efficiency improvement technologies to ships. Since 2009, IMO has developed significant energy efficiency improvement regulations towards sustainable shipping by adopting many measures such as, SEEMP[1], EEDI[2], and EEOI[3]. Therefore, developing a global fuel oil consumption database for the shipping industry is another significant step towards green shipping.

In promoting energy efficiency in the shipping industry, IMO's Data Collection System (DCS), proposed on 28 October 2016 at the Marine Environment Protection Committee 70 (MEPC70), a substantial step towards achieving green shipping which is expected to make other energy efficiency measures more transparent, effective and measurable. Measuring is the most important activity of energy efficiency, if it cannot be measured, it cannot be controlled. A detailed inventory will thus allow policy makers to determine the magnitude of pollution and pace of the decision making and adopt global regulations regarding shipping emission. The Monitoring, Reporting and Verification (MRV)[4] system is the key element for good governance. Similarly, the MRV system is the core of Energy Management, without MRV other energy efficiency measures may not be effectively implemented. A system's performance, operational parameters, indicating measurements and status quo need to be studied, evaluated and analyzed for a certain period of time before any policy is taken into consideration for Energy efficiency improvement.

In the case of the European Union (EU), all transport modes, including the maritime sector, to a certain extent emissions are measured and controlled under strict mandatory regulations and participation in the EU climate initiative (EU-ETS). As such, the integration of MRV into EU policy to reduce emission from the shipping industry is the

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[1] Shipboard Energy Efficiency Management Plan
[2] Energy Efficiency Design Index
[3] Energy Efficiency Operational Index
[4] IMO-DCS and EU-MRV have minor differences and are considered as synonymous in this paper. In many places, both of these systems are mentioned as MRV system as a common term in this dissertation, otherwise, it is specifically expressed.

primary reason for the adaptation of such a system. In the EU, maritime transportation has increased by 48% between 1990 to 2007 (EUR-Lex, n. d.). The EU Regulation (EU) 2015/757 considers that EEDI, EEOI and SEEMP alone may not be sufficient to reduce greenhouse gas emission, therefore, it is essential to adopt a more stringent policy framework. In EU Regulation (EU) 2015/757 the introduction of MRV is justified as a benchmarking tool for shipping Energy efficiency measurement. In 2030 the framework of EU (Regulation EU 2015/757) target for reducing GHG pollution from domestic sources is to be reduced by at least 40% compared to the 1990 level. The intension of the implementation of EU-MRV is that it could serve as a model which will facilitate the smooth global adoption of such system.

From a shipping company's perspective, the effective implementation of MRV not only gives competitive advantages in the market, but keeps it upfront in the race. Moreover, energy saved from energy efficiency enhancement measures could compensate a system implementation cost. IMO adopted EEOI and SEEMP in 2013, however, some ambiguity still exists on the reporting format, the development of a comprehensive monitoring plan and monitoring procedures for fuel consumption. The MRV system is mandatory and will be requiring verification at each step by authorized verifiers. The organizational capabilities such as technical, financial and human aspects to ensure the effective implementation of such regulations is equally essential at an organizational level in any shipping company. To bridge this gap and ensure a smooth transition from a conventional system to a modern MRV system, research is required focusing on specific areas of concern.

1.2 Literature Review

Research on MRV is a relatively new area of study in the shipping industry and still at the introductory phase. Only a few research studies have been conducted a study on maritime

MRV systems, therefore, the literature on maritime MRV is limited. However, available literature and resource material have been reviewed as much as possible from multiple sources and dimensions in the maritime industry. In addition, literature concerning MRV in other sectors were visited in order to better understand the maritime industry for benchmarking and gap analyses. There are emerging issues in the context of the maritime MRV process as highlighted below.

Successful MRV regimes Schakenbach, Vollaro and Forte (2012) describe the fundamentals of effective and fruitful implementation of the MRV system and MBM such as the Cap-And-Trade system for monitoring Acid Rain Program (ARP) and Nox Budget Trading Program (NBTP) in the United States. The paper stresses the MRV elements which basically support and include strong compliance, quality assurance, accuracy and completeness of data, centralized monitoring, level playing field, and emission reduction incentives. Reviewing the successful MRV regimes could facilitate the identification of barriers and actions towards effective elimination. Paulsen and Johnson (2015) describe the current best practices and challenges of implementing the MRV system in the maritime field. This paper also explains the policy makers and different stakeholder's roles in adopting energy efficiency practices which could also ensure effective participation in the MRV process.

Regulatory progresses There are many regulatory developments for the maritime industry in the IMO and EU regarding energy efficiency and the MRV process which are required to be visited to reveal gaps and impeccable compliance. The IMO second and third GHG studies, 2009 and 2014, have presented detailed images of shipping emissions, trend and trajectories for future scenarios. MARPOL Annex VI, Regulation 22A for Data Collection System, Resolution.MEPC278(70) for MARPOL Regulation 22A amendments, Marine Environment Protection Committee (MEPC) guidelines of calculation of EEDI [Res. MEPC.245(66)], EEOI (MEPC.1/Circ.684, 2009) and SEEMP

[Res.MEPC282(70)] are all sources of the regulatory directions and procedures for GHG emission reductions. The Regulation (EU) 2015/757 of the European Parliament and of the IMO Council of 29 April 2015, are the main guidelines for the EU-MRV as it sets the procedures for the different stakeholders in the MRV regime for ships over 5000GT. The regulation emphasizes the reduction of uncertainty, maintaining accuracy, removing data gaps and barriers for a robust MRV system. In MEPC71, July 2017, various resolutions and guidelines were adopted for the MRV system, such as guidelines for maintaining fuel consumption database, using GISIS as information platform for the DCS, and policy on proxy for transport work.

Technological issues Fan, Yan, and Yin (2016) discusses the multisource information system for the effective monitoring technology to allow real time seamless data collection, monitoring and identifying potential for technological improvement for Energy efficiency. The paper illustrates how technology could be incorporated into a vessel's monitoring and data transmission system for improving the management of shipboard dynamic and static data.

The effective implementation of MRV will only come true when all the data uncertainty has been identified and resolved. Insel (2008) describes the uncertainty of speed and power measurements which occur in changing sea states and other changes affecting the measurement readings. As such, applying similar process for removing of data uncertainty from the MRV related source of data should be examined to facilitate the robust, credible, accurate and reliable MRV process.

A modern and well-equipped vessel with correct methods for data collection can only ensure efficient, accurate and proper compliance to the regulatory requirements. Need for technological improvement is also reflected by IMO's 2025 targets for new ships to make 30% energy efficient in the future. The implementation of the MRV system through the

IMO or EU will also boost technological improvement in the instrumentation and data collection system. The accurate data acquired by the new data collection system will also help IMO to develop a vision for the shipping sector (IMO, 2017). An assessment of the technological gap, trend, development, preferences, and procedures followed by the shipping sector is a necessary prior implementation of the new data collection system and this is the focus of this research.

TOPSIS Model The selection of the monitoring method is vital for the MRV system. According to Olcer, 2008, multi-objective combinatorial optimization for multi conflicting objectives is really a complicated decision-making process. These Multiple Attributes Decision Making (MADM) techniques are used in the ship design process. The Technique for Order of Preference to Ideal Solution (TOPSIS) method could be employed and achieve the best and worst solution ranking of the alternatives while the effective implementation of the MRV process could be ensured by better decision making at the outset. For the ship design process this method is used for determining the best design feature for a MADM problem. Therefore, this a new approach to apply TOPSIS model for selecting best fuel consumption monitoring.

Energy efficiency: Human perspective The efficiency of the data collection system largely depends on the knowledge, awareness, training and overall expertise of persons involved in the process. A system or policy is as effective as the person who is acting upon it. Building training and awareness is essential for delivering specific skills for particular work. Kitada and Olcer, in 2015, discussed the problem of not achieving expected progress in Energy efficiency in shipping sectors is more attributed to the human element connected to the technology and using it. Besides policy and technology, the human element is also a concern for effective implementation of the MRV system which will be explored by this dissertation.

Barriers to energy efficiency in shipping Jafarzadeh & Utne, (2014) identify the barriers to energy efficiency in the shipping industry from multiple perspectives, such as information, economic, intra-organizational, inter-organizational, technological, policy and geographical barriers. Many barriers identified in this study is relevant to the potential barriers for the MRV process. However, the MRV related barriers are more oriented to the policy, technology, human and data quality. In-depth study on vessel's documentations, fuel consumption monitoring methods and analyzing the shipping industry's standpoint is essential for identification of the barriers to the MRV process.

1.3 Objective

The main focus of the research is to find out the barriers and constraints of the implementation of the MRV system in the shipping industry. In doing so, the research focuses on:

- the efficiency of the current energy efficiency regime (SEEMP and EEOI) and gaps with the MRV system,
- the identification of barriers in different dimensions, such as policy, technological, human factor, and maintaining data quality,
- the identification and recommendation on how data accuracy and robustness can be maintained for the effective implementation of the MRV system.

1.4 Methodology

The methodology for the research is a quantitative approach involving an online survey distributed among maritime experts working as shipping managers, classification society surveyors, ship's masters, chief engineers, navigating officers and engineers. An online survey under a specifically designed questionnaire to the relevant persons will help to gain insight of the shipping industry's energy efficiency status quo and benchmark while revealing the barriers of organization, human elements and the data gap. Taking into account the short timeframe and complexity of the research, the survey has to be carried out online, as this can give wider access to the maritime community in the quickest time to get feedback. Scarcity of resources and time make it difficult to visit places and interview face-to-face. Thus, surveying online has been decided to be more effective in this regard. The questionnaire on required technological status onboard ship for the improvement of data quality was also incorporated.

Developing a survey questionnaire is challenging as multiple factors have to be looked into to make it effective and successful. A survey questionnaire is considered as a conversation with the respondents regarding the subject matter. The internet survey questions need to be so constructed that it has to be simple and easy to understand. It has to be clear to avoid misunderstanding, misinterpretation and can be skipped if the reader does not want to answer. Again, the appearance of individual pages, question's order and format could be influencing factors for the decision and responses (Dillman, 2007). Therefore, the careful construction of a questionnaire could deliver better responses and successful survey. The survey questionnaire of this research will be targeted to the whole maritime cluster including Navigational officers, Masters, Ship's Engineers, Ship Managers, Surveyors, and people working in maritime administration in the government organizations. The addition of excessive technical matters to the survey questionnaire have been avoided to retain the simplicity of the questionnaire.

In addition, the vessel's various data inputs such as the Engine room log book, Chief engineer's log abstract, fuel equipment, methodologies for fuel consumption measurement, dynamic data related to energy efficiency, EEOI and SEEMP will be reviewed and the data gap will be analyzed. A comparison between the IMO-DCS and EU-MRV on the basis of existing regulations will be established and distinguishing characteristics will be identified.

Finally, after achieving the results from the evaluation of the vessel perspective and outcome of the online survey questionnaire, the significant barriers to the uptake of MRV will be identified. A TOPSIS model will be created to assess the fuel consumption data collection methodologies of a vessel to compare under different attributes such as data error, Capital Expenses (CAPEX), Operational Expenses (OPEX) and the respondent's rating of fuel consumption methodologies from the online survey. The most preferable method for data collection could be forecasted with the employment of the MADM method. The analysis of the TOPSIS model will display a factual picture on maintaining data accuracy and quality.

1.5 Expected outcomes

This research will identify the constraints and barriers for effective implementation of the MRV systems and enable to mitigate in an efficient way. This research will suggest the suitable best steps to consider for the fuel consumption monitoring and guide to develop strategic instruments for MRV implementation.

1.6 Structure of the dissertation

Figure 1 represents the design and chapter wise presentation of the research which employs various scientific methods to facilitate the effective implementation of MRV in the shipping industry.

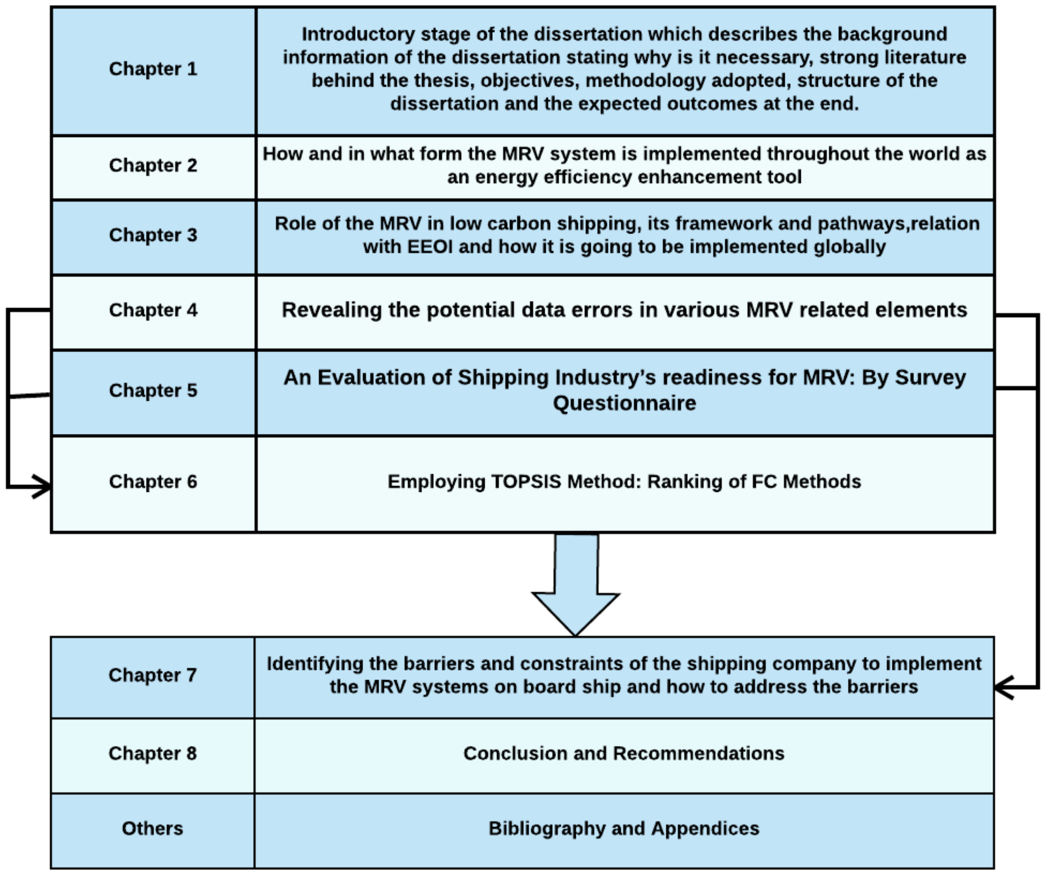

Figure 1: Structure of the dissertation

The arrows in the Figure 1, display the flow of information between the segments of the dissertation. The data obtained by examining the potential data errors in various MRV elements in Chapter 4 and online survey outcome in the Chapter 5 are fed into the TOPSIS model in Chapter 6. Similarly, analysis in theses chapters are aiding to the identification of barriers, in Chapter 7, to the MRV process towards obtaining the objectives of the research.

Chapter II

MRV in Other Sectors

2.1 Overview

The MRV process is successful in many areas having a wide range of positive impact on emission reduction including the protection of forestry and agriculture and improving human health. MRV is also considered as the precursor for Clean Development Mechanism (CDM) and Joint Implementation (JI) under the United Nation Framework Convention for Climate Change (UNFCCC). The inventory of GHG emissions, evaluating, monitoring and sharing information with all parties are necessary to implement the CDM and JI for taking required actions (UNFCCC, 2017). The following sections provide an overview of recent successful MRV practices in various domains.

2.2 The MRV for National GHG Measurement

During the recent years, the MRV system has been adopted in many areas all over the world. In the Conference of Parties 21 (COP21): Paris agreement, the MRV system forms an integral part as all parties agree to take part in the global stocktaking for their emissions. The processes under COP21 are identifying sources of emission, taking an inventory against their Intended Nationally Determined Contributions (INDC's) and to report to the United Nations (UN) to form a MRV database. MRV is an important part of the COP21 Agreement as all parties to the agreement must identify their Nationally Determined Contributions (NDCs) and report to the central database of the UN where further studies on a global scale are conducted and potential improvement activities are being analyzed. The Governments are developing National MRV-Systems to meet the global standard on cutting GHG production. For the COP21 agreement to become effective, the governments should develop a partnership support for the design set-up and effectively implement Low-

Emission Development Strategies (LEDS), Nationally Appropriate Mitigation Actions (NAMAs) and MRV systems in their countries of jurisdiction (Pang et al., 2014).

2.3 The MRV Process for Forestry

As the national GHG measurement program of MRV under UNFCCC, the UN's Reduction of Emission from Deforestation and Forest Degradation (REDD+) program, was launched in 2008. It is a cooperative approach to help developing countries adopt expertise and technical knowledge on REDD+ issues with the help of the Food and Agricultural Organization (FAO) and United Nations Development Program (UNDP). The program helps national authorities to implement the REDD+ program involving all stakeholders at the national and international levels. Under the UNFCCC, the REDD+ countries require to establish robust and transparent forest MRV systems. The MRV system is required to cover all types of forests to minimize double counting and leakage. The key principles for good governance for MRV is transparency, accountability and participation (Ochieng, Visseren-Hamakers, Arts, Brockhaus, & Herold, 2016) .

2.4 The MRV for Various Emission Trading Scheme (ETS)

Using MRV elements, the United States Environment Protection Agency (EPA) has developed and implemented an Acid Rain Program (ARP) and NOx Budget Training Program (NBTP) which ensures strong quality assessment and compliance through penalties and incentives (Schakenbach, Vollaro, & Forte, 2006). The ARP regulates Sulphur Oxides (SO_2) and Nitrogen Oxides (NOx) emissions from power generators of more than 25MW which burn fossil fuels. The SO_2 controlling part of the ARP is a Cap-and-Trade Program which is designed to reduce the emission of SO_2 in the United States. These programs are based on MRV systems which has gained public confidence, as it maintains high accuracy and completeness of emission data (Schakenbach et al., 2006). Again, as the EU's climate change policy, the EU-Emission Trading Scheme (EU-ETS) is an extraordinary example for a Market-Based-Measure (MBM) which is effective in 31 countries and controlling 45% of the EU's GHG emission. EU-ETS shows effectiveness in the reduction of emission as a GHG emission having been reduced by 5% in 2015 compared to 2013. Within the EU-ETS Cap-and-Trade system, a company may receive or sell "Emission Allowances" and they can also buy "International emission reduction credits" for emission reduction projects around the world (European Commission, 2017). The effectiveness of the ETS largely depends on the effective implementation of MRV systems across all industries.

2.5: Summary

Monitoring and evaluation of the forestry project accurately determine the impact of the project on the GHG emissions for country's impact on climate change (Vine, Sathaye, & Makundi, 2000). A MRV system is extremely beneficial for any system monitoring and data collection regime. It creates transparency, completeness, high accuracy and effectiveness within a system. Therefore, it heightens the public confidence on the system. It is equally true for all the MRV programs discussed in this chapter. The MRV is proven successful in many areas, the best practices and lesson-learnt can be helpful for the implementation of the shipping MRV. The usefulness of the shipping MRV system is being recognized recently to cut down the emissions from the maritime transport in the future.

Chapter III

MRV in Low-Carbon Shipping

3.1 Overview

The shipping MRV will increase the efficiency of the global maritime emissions reduction initiatives. None of the emission reduction ideas could be effectively implemented without a MRV system; the MRV would act as a precursor for any MBM. A clear understanding of the MRV process is necessary for the effective implementation of the system. This chapter discusses the entire shipping MRV process including the regulatory procedures in the IMO and EU and a comparative study with the other existing energy efficiency measures. A discussion on the fuel consumption monitoring methods and issues related to each method have been reviewed concisely.

3.2 MRV as a Market Based Measure for Maritime Transport

According to the MEPC 61 information paper (IMO, 2010), the Experts Group's feasibility study was undertaken to reduce GHG emission from ships. The study represents proposals for different MBM's by various countries in the meeting, such as GHG Fund for Ship, Leveraged Incentive Scheme (part of GHG fund goes for good ships), Port states levy (award to green and efficient ship), Ship's Efficiency and Credit Trading, Vessel Efficiency System, Global Emission Trading Scheme for international Shipping, and Emission Trading Scheme. These abatement proposals could be effectively enforced when emissions from maritime transport is inventoried and under the continuous monitoring regime. The stringent regulations and economic incentives on energy efficiency are the driving forces, which will influence a company to invest in GHG abatement technologies and achieve significant reduction of GHG in maritime transport (IMO, 2010).

These MBM's require the benchmarking of the shipping emission with robust data and the monitoring of emissions from the entire maritime transport sector. The need for

MBM's in the shipping industry actually leads to further developments in the legal instruments and the adoption of DCS by IMO.

3.3 The Framework and Pathways of MRV in Maritime Transport

Bellassen et al., (2015) provide definition for a MRV process:

"Monitoring" covers the scientific part of the MRV process. It involves getting a number for each variable part of the equation that results in the emissions estimate. This range of direct measurement of gas concentration using gas meters to the recording of proxies such as fuel consumption based on the bills of a given entity.

"Reporting" covers the administrative part of the process. It involves aggregating and recording the numbers, explaining how you came up with them in the requested format, and communicating the results to the relevant authority such as the regulator or the top management of the company.

"The purpose of *Verification*" is to detect errors resulting from either innocent mistakes or fraudulent reporting. It is usually conducted by the party not involved in the monitoring and reporting, who checks that these two steps were conducted in compliance with the relevant guidelines.

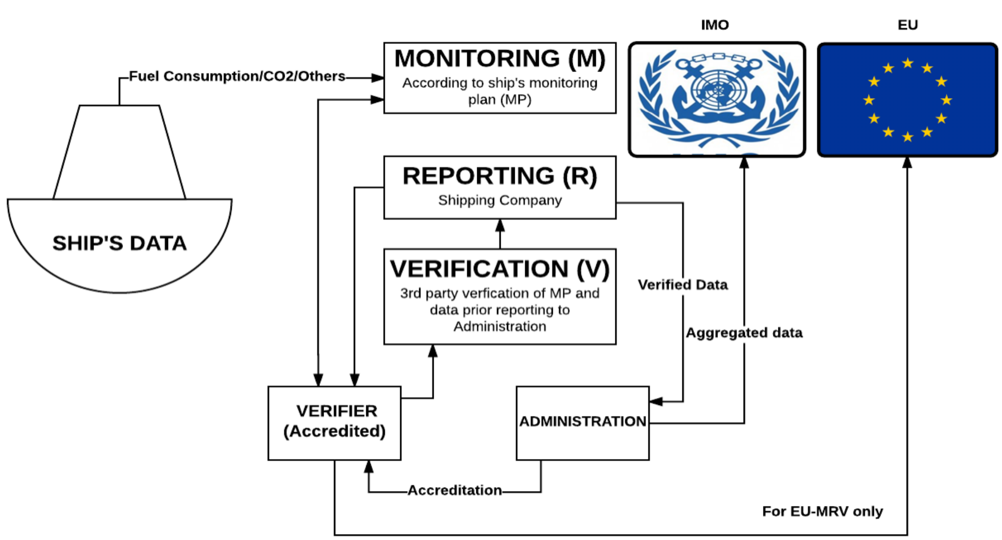

Figure 2: MRV System, Source: Author

The *Maritime-MRV* can be defined as a process of continuously measuring any fuel consumption of ships aiming to form a centralized global database with standardized data collection and reporting mechanisms according to a structured and verified monitoring plan developed under the IMO guidelines.

A simplistic process flow chart of the MRV regime under IMO and EU is represented in Figure 2 where different stake holders, such as, the vessel, verifier, administration and IMO/EU's relations and links on MRV process are established.

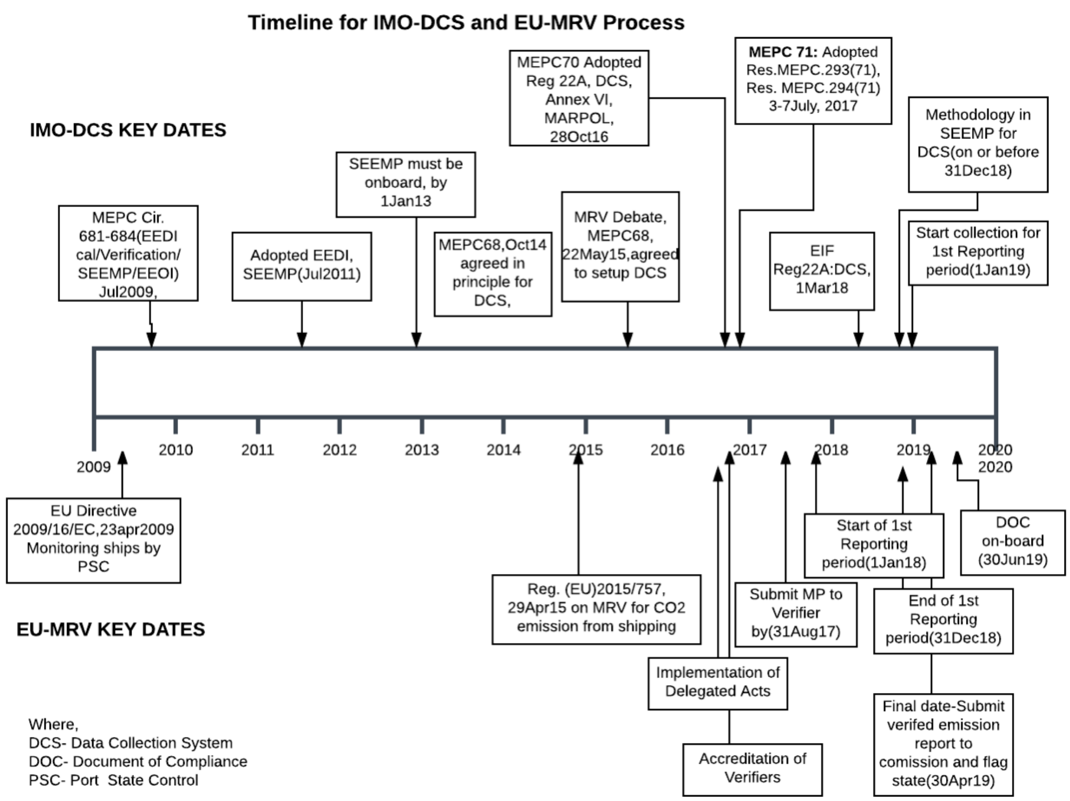

Figure 3: Key dates and timeline for IMO-DCS and EU-MRV System

In Figure 3, the key dates and timeline of IMO-DCS and the EU-MRV System are presented which portrays the international efforts and regulatory developments in the IMO and EU.

3.3.1 IMO- Data Collection System

The goal of the IMO-DCS is to establish a global fuel consumption database which requires a robust uninterrupted data flow and undisturbed link between all the stakeholders involved in the process. Maintaining data quality and the effective participation of all stakeholders are a matter of concern.

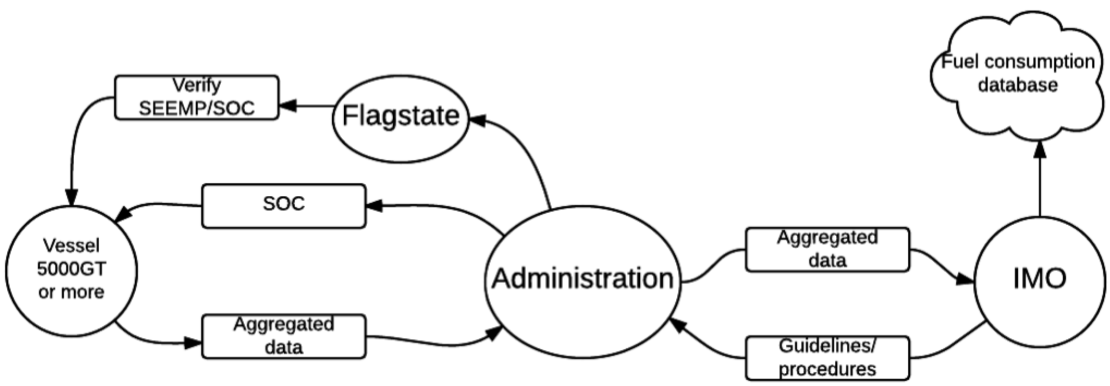

Figure 4: IMO-DCS, Data flow, Source: Based on Res. MEPC.278(70)

Figure 4 displays the data flow between the responsible parties in the IMO-DCS. Recently, IMO has taken numerous steps towards improving the energy efficiency of vessels which includes SEEMP, the mandatory requirement of EEDI for new ships, the EEOI for existing ships and the Fuel Consumption Data Collection System for ships of GRT 5000 and over. In MEPC 71, IMO adopted the following procedures for the Fuel Consumption Data Collection System, such as guidelines for the Administration on verification of ship fuel oil consumption data and guidelines for the development and management of the IMO ship fuel oil consumption database which are the latest substantial development in this regard. The platform for fuel consumption database will be the GISIS database with secured access. A circular on the submission of data to the IMO data collection system of fuel oil consumption data from a ship that is not entitled to fly the flag of a Party to MARPOL Annex VI was also published in the session. Additionally, some proposals have been made for the proxy of transport work for offshore and contracting vessels and ice class ships (IMO, 2017).

Important issues regarding the data collection system were addressed by MEPC 70 in November, 2016. The definitions and clarifications of various terms such as distance travelled, the company, and cargo have been described in detail. The year of construction is not included to maintain anonymity of a ship. At MEPC 70, the committee agreed that the voluntary implementation of data collection system could be considered by a company prior to the regulation kicking off, however, it will not be forming part of the database. The company can also start voluntary reporting for the familiarization of staff who will take part in the collection process.

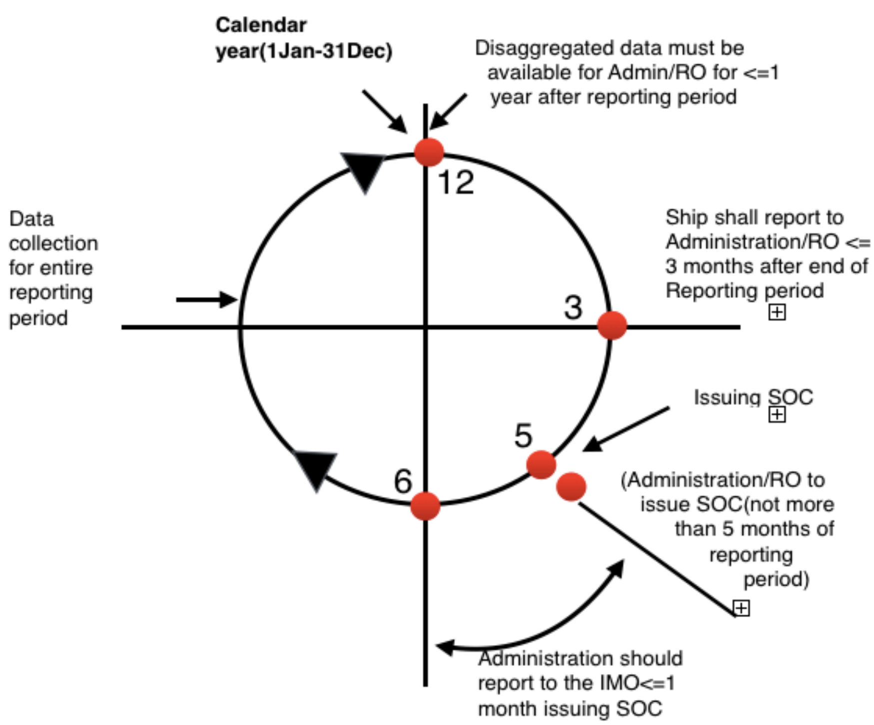

Figure 5: IMO-DCS Cycle

According to MARPOL, Annex VI, Reg. 22A, the methodology for data collection should be included in the SEEMP and verified by the Administration or Recognized Organizations (RO) on behalf of the Administration. The above representation, in Figure 5, better displays how the whole process of the MRV system will incessantly run in the future.

3.3.2 The European Union (EU) MRV

The EU MRV is the part of the Union-wide emission reduction scheme which is 40% reduction of emission of 1990 levels in 2030. The EU expect that the Implementation of MRV will cause 2% of the reduction of shipping emission in the EU region compared to the BAU scenario in the future (EU Commission). The staged approach of the EU MRV for the future emission abatement techniques will be subjected to various barriers and benefits on implementation.

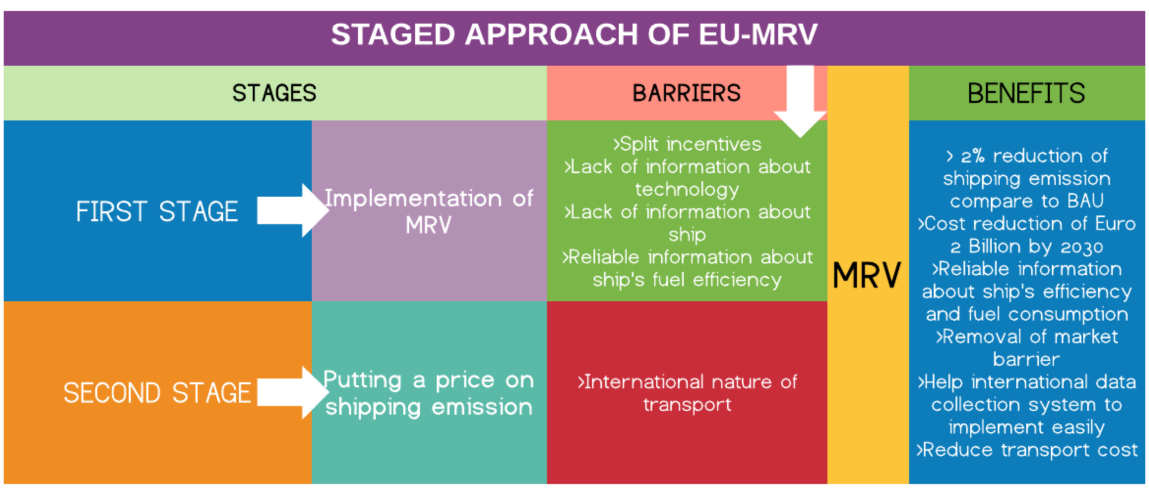

Figure 6: Staged approach of EU-MRV[5], Adopted from Regulation (EU) 2015/757.

[5] Based on Regulation EU 2015/757 of the European Parliament of the Council of 29 April 2015

The EU-MRV system will act as a model system for the global MRV system as companies operating their vessel in the EU region will have to comply with the EU-MRV regulation prior to the IMO-DCS coming into effect. Moreover, the outcome of the EU-MRV and information and experience learnt from the EU-MRV system, establishing a CO2 emission database, will be shared with the IMO for member states to take the necessary steps for the adoption of IMO-DCS (EUR-Lex, n. d.).

Developing a monitoring plan verified by an accredited verifier for a MRV system is vital. It requires a series of assessments involving a complete data collection, storage and transmission processes. A monitoring plan is considered as a backbone of the MRV system which should be reviewed regularly, at least once in a year (EUR-Lex, n. d.). According to the EU-MRV (EUR-Lex, n. d.), several procedures have to be included in its Monitoring Plan, such as, the measurement of fuel uplift and fuel in the bunker tanks, ensuring the uncertainty of fuel measurement consistent with the requirement in the regulation and fuel suppliers accuracy standard, recording and determining the distance travelled, cargo carried, time spent at sea and detecting surrogate data and eliminating data gaps.

Ships over 5000 DWT arriving at, within or departing from an EU port are required to collect data both annually and on a per voyage basis and to report CO2 emissions to the Commission. The MRV system requires various stakeholders to participate simultaneously to contribute for an effective MRV system. A holistic picture of the MRV process involving all stakeholder's, and a process flow chart of data for the EU-MRV, are presented in the Figure 7.

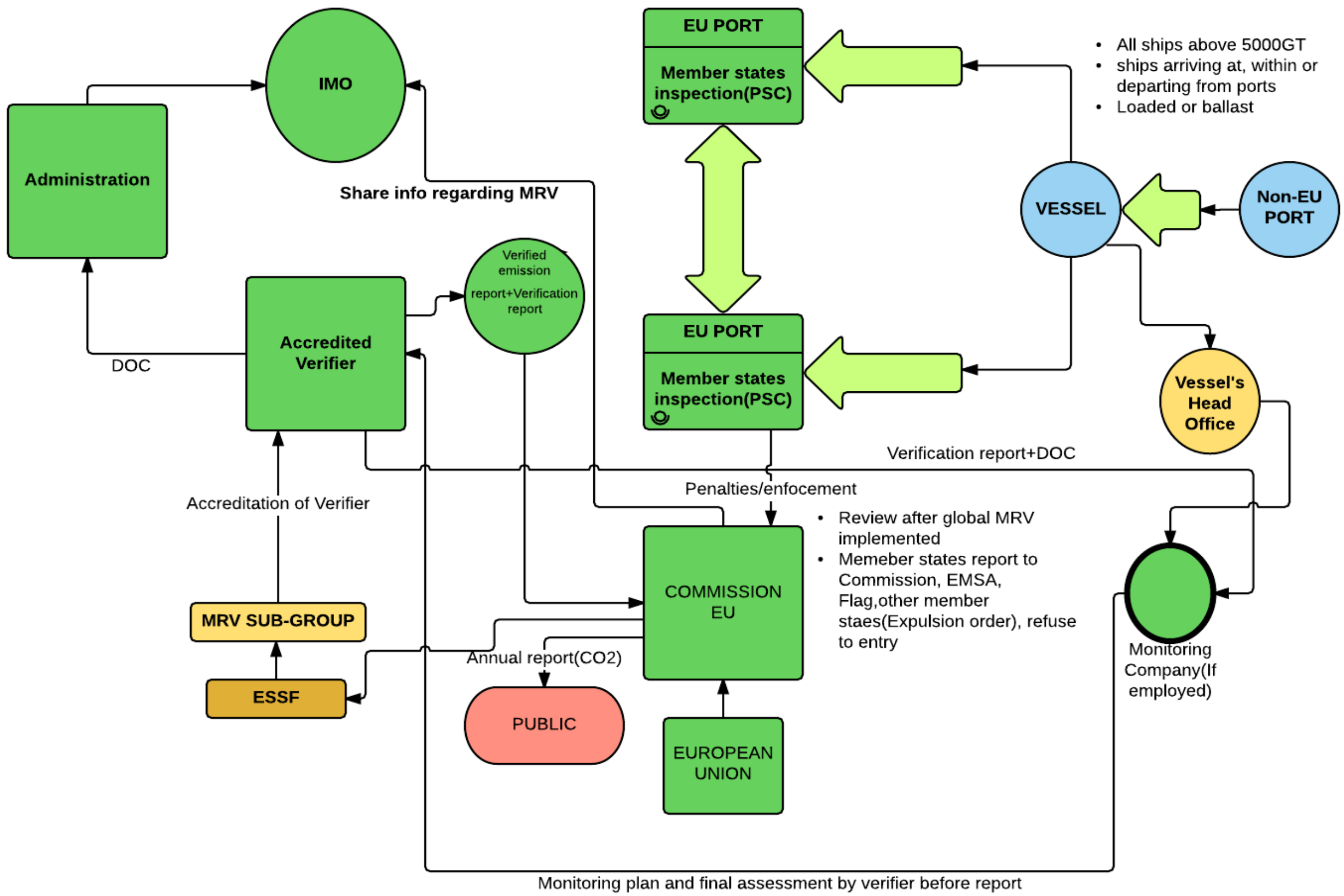

Figure 7: EU-MRV Process

3.3.3 Comparison of Data Requirement for the IMO-DCS and EU-MRV system

IMO-DCS and EU-MRV are similar in many areas, however, some differences exist in the reporting requirements, for example level of uncertainty, average energy efficiency of vessel and emission factor. The full comparison between the IMO-DCS and EU-MRV is illustrated in Table 1 below.

Table 1: Comparison of IMO-DCS and EU-MRV Process

(Based on Appendix IX, Res. MEPC.278(70) and EU Regulation (EU) 2015/757)

Type	IMO-DCS	EU-MRV SYSTEM
	Data anonymity ensured	All vessels emission data will be broadcasted
VARIABLE	Total Fuel Consumption for all systems	Total Fuel Consumption and CO_2 Emitted -Aggregated CO2 and fuel consumption for all voyage, in EU, arrival/Departure from EU port -including laden voyage, cargo heating consumption (voluntary)
	Method for Fuel Consumption Measurement: 3 Methods • Using Bunker Delivery Notes (BDN) and periodic stocktaking • Using Flowmeter (FM) • Bunker FOT Monitoring on board	Method for Fuel Consumption Measurement: 4 Methods • Using Bunker Delivery Notes (BDN) and periodic stocktaking • Using Flowmeter (FM) • Bunker FOT Monitoring on board • ***Direct Measurement Method*** (From Exhaust Gas Uptake) ***Part C:*** • Emission source, Monitoring method and related ***level of uncertainty*** (% per monitoring method use)
	Distance Travelled over ground	Total Distance travelled (Nm) over ground.
	Hours underway (under own Propulsion)	Hours under way (Time spent at sea)
	Type of Fuel Used (Different fuel collected separately)	Type of Fuel Used (Different fuel collected separately), ***Emission Factor for each fuel used.***
	Report End Date (dd/mm/yyyy)	Date and Time of Arrival (To be recorded for per voyage monitoring)
	Report start Date (dd/mm/yyyy)	Date and Time of Departure (To be recorded for per voyage monitoring)
		Transport work and total transport work
		Average Density of cargo carried in reporting period
		Average Energy efficiency[1]: FC/Distance (kg/Nm), FC/Transport work, CO2/Distance, CO2/Transport work, Average EE/Transport work, Differentiated Average EE for laden voyage (FC and CO2 emitted-kg/T-m, gmCO2/T-m), Average EEOI (voluntary)
FIXED	Rated Power Output: • Main Engine (KW) • Aux. Engine (KW)	Ship Name/ IMO No./Port of Registry or Home port/Ship owner, Company, Contact person and Verifier: Name, Address and details of contact, Verifier's Accreditation no. and Statement of Verifier
	EEDI Value (If applicable)	EEDI of EIV (gm-CO_2/T-M)
	Vessel DWT	
	Vessel Net Tonnage (NT), If applicable	
	Gross Tonnage (GT)	Port of registry or Home port
	Ship Type	Ship Type
	IMO Number	IMO Number
	Ice Class of ship PC1-PC7 (if applicable)	Ice Class of ship PC1-PC7 (if applicable)

3.3.4 Data Collection Plan or Monitoring Plan

SEEMP specifies that ships of 5000GT and above need to have a Data Collection Plan which has to be included in the SEEMP with the specific methodology used for data collection in resolution Res.MEPC.282(70). According to resolution Res.MEPC.282(70), to ensure no data gap the correction procedures and steps to take in case of flowmeter malfunction and addressing the missing data necessary for the Data Collection Plan. The MARPOL Annex VI Regulation 22A suggests that the data needs to be submitted electronically in prescribed the format. Some regulatory ambiguities have been defined in the regulations 22A, MARPOL Annex VI and EC Reg. (EU) 2015/757, such as, *Port of call, Distance travelled*, *Hours underway* and *Voyage*. *Port of call* is where ship stops[6] for loading or unloading cargo and/or embarking/disembarking passengers. Distance travelled, while the ship is underway[7] using its own power, should be calculated as "Distance over ground" (MARPOL Annex VI, Reg.2). *Hours underway* should be calculated while the ship is using its own propulsion. *Voyage* is for the purpose of loading or unloading cargo and/or embarking and/or disembarking passengers between the port of calls.

3.3.5 Fuel Consumption Monitoring and Interpretation

Each type of fuel consumption must be calculated separately and all the inventory is to be recorded. The consistency, accuracy, completeness and transparency of the fuel consumption monitoring methods should be maintained throughout the process. The company may select different types of fuel consumption monitoring methods, however, detailed procedures, fuel systems of various use and the responsibilities of each person involved in the process must be described in detail in the SEEMP or MP wherever it is applicable (Res.MEPC.282(70)). Any change must be reflected in the plan and notified to the Administration or verifier if the plan is reviewed. The SEEMP should be reviewed on a regular basis and at least annually. A company may select any one of the fuel consumption monitoring methods:

a) Method-A: Bunker Delivery Note (BDN) and Periodic stock taking in fuel tanks

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[6] Other activities such as bunkering, Ship-to Ship transfer, obtaining supplies, crew change, stop for repair, dry docking, need assistance or shelter for adverse conditions are not considered as a port of call.

[7] Using satellite or other methods which should be described in the SEEMP in the DCP section. Any other method for calculating distance over ground should be included in the DCP. Distance travelled which needs to be recorded in the ship's log book.

b) Method-B: Regular Stocktaking of the bunker tanks
c) Method-C: Reading from Flowmeters
d) Method-D: Direct measurement from the exhaust gas outlet

3.3.5.1 Method-A: Bunker Delivery Note (BDN) and Periodic Stock Taking in Fuel Tanks

Fuel consumption in a reporting period can be calculated as below:

Fuel at the beginning of the reporting period = Q_A

Bunkered quantity as per BDN= Q_B

Fuel oil available at the end of reporting period = Q_E

Debunker quantity of fuel= Q_D

So, Fuel Consumption for the reporting period, FC= $(Q_A + Q_B) - (Q_E + Q_D)$

The annual fuel consumption to be determined in the same method as described in the IMO Data Collection Plan according to the guideline of Res MEPC.282(70). The De-bunkered quantity has to be based on the Oil Record Book. The FO quantity in BDN has been considered to take into account the calculation in conjunction with periodic stocktaking in the fuel tanks. According to MARPOL Annex VI, BDN has to be kept onboard for three years after the delivery of fuel. Some may consider this process can be easily complied with. However, the error in fuel calculation will not be entirely eliminated. In many cases, discrepancy occurs in BDN quantity and the supplied quantity due to the short delivery to the vessel by supplier. The inaccurate and fraudulent delivery caused by the "Cappuccino Effect" and the excessive water content in the fuel which vaporizes and reduces the quantity after a while at storage. The quantity dispute may not be solved once BDN is signed by the parties and the quantity shortage may not be reported. Vessel may try to match the quantity by adjusting the fuel figure intentionally showing the consumption is slightly high. For this reason, many chief engineers tend to keep an undeclared excess quantity of FO to adjust at a later time in a similar situation. Normally, around 0.5% of water exists in the FO which is evaporated or separated through a purifier. A small quantity of FO is lost through the FO transfer, separation and filtration processes which cannot be counted if BDN and periodic stock taking is considered for the reporting fuel consumption. If we consider this type of error in a global scale, it will be the equivalent to millions of tons of FO or CO_2 emission in a year. However, in Res MEPC.282(70) the guidelines for SEEMP states that any supplemented the data used for eliminating data gap or differences has to be recorded and supported with documentary evidence. All losses have to be taken into consideration.

Periodic stock taking is not exactly the same as described in the Method-B, as regulation demands for FO tanks stocktaking which needs to be taken at the beginning and at the end of the reporting period. In the case of EU-MRV, the periodic stocktaking has to be regularly recorded and every beginning or end of voyage and also for the entire reporting period. The error in the periodic stock taking could be minimized, in some cases eliminated, by automated tank gauging devices fitted in the bunker tank to obtain the readings remotely. The accuracy and reliability must be ensured by the regular calibration of the gauge and ensuring certified equipment by the administration if fitted. The manual dip sounding process is more accurate when the vessel is at calm weather condition with no rolling or pitching which gives an error in reading. At sea when the vessel is in motion sometimes erratic readings may give an inconsistency in the fuel tank gauge readings and the CO2 emission data may be affected. Similarly, this could be applicable to the Method-B which entirely depends on the stocktaking of the bunker tanks.

3.3.5.2 Method-B: Regular stocktaking of bunker tanks

Vessels carry out daily Fuel Oil (FO) stocktaking of the bunker tanks usually by the manual dip sounding process or remote gauge monitoring. As discussed in section 3.2.5.1, the error in the manual dip soundings process is larger than in the automated system if precision equipment is fitted for the automated tank gauging system. Miscalculation, erroneous dip soundings of tanks, misreporting, equipment with high errors and losses in the system can end up as wrong FO Consumption. The Res MEPC.282(70) guidelines suggest to take tank reading by three methods namely- the automated system, soundings and dip tapes and tank measuring which should take place daily.

3.3.5.3 Method-C: Reading from Flowmeters

The method is fully based on the Flowmeter reading fitted in the FO supply systems of a machinery, the accuracy of the reading depends on the error margin of the flow meter and personal or automated recording of readings. The administration must satisfy after verification that the flow meters are calibrated on a regular basis and specification satisfying MARPOL NOx Technical Code. The necessary equipment's calibration report should be available on board the vessel.

Annual Fuel Oil Consumption= Summation of Flowmeter reading in a calendar year

According to Res MEPC.282(70) guidelines, other methods could be considered as backup measurement methods in the case of the breakdown of flow meters, however, any methods undertaken for bunker tank monitoring must be described in the SEEMP part II in detail including the calibration method of the flowmeter stating accuracy.

3.3.5.4 Method-D: Direct Measurement from Exhaust Gas Outlet

In this method, applicable to the EU-MRV, data is obtained from the readings of the direct flow measurement of gases in the funnel exhaust stake which is then relayed as quantity of CO_2 emission or fuel consumption as required by the operator. Many types of exhaust gas analyzers with high precision, approved by international standards, are available in the market. In terms of the data collection, transfer and processing of this equipment it could be considered convenient for the vessel's crew. However, reliability and maintenance considering the harsh marine environment could be an issue. According to expert opinions the following can be agreed, as presented in the Table 2, regarding the many factors of fuel consumption monitoring methods.

Table 2: Fuel consumption monitoring methods

Criteria	Method A	Method B	Method C	Method D
Process	BDN+ Periodic stock taking	Regular stock taking of bunker tanks	Flowmeters reading	Exhaust gas flow measurement
Applicability	IMO and EU	IMO and EU	IMO and EU	EU
Effect of external factors on accuracy	Low	Moderate	Moderate	Low
Obtaining reading from remote location	No	To a certain extent	To a certain extent	Yes
Technological involvement	Less involvement	Moderate involvement	Moderate involvement	High involvement
Human interaction	High involvement	Moderate involvement	Moderate involvement	Less involvement

3.3.5.5 Emission Factor

Marine fuels specifications are regulated by the ISO8217: 2017 standard as amended in 2017. Sometimes, the emission factors for conventional factors are not up to date with the industry trend, ISO8217: 2017 which has included properties of biofuels blend and Distillate FAME (DF) grades such as DFA, DFZ and DFB that contains fatty acid up to 7%. With the use of more generic values of the emission factor, this increases the uncertainty in emission measurement calculation (Einemo, 2017). The value of the emission factor has to be taken to convert to the CO2 emission as per IMO recommended value in the Nox Technical Code, whereas, EU-MRV Regulation (EU) 2015/757 takes the International Panel for Climate Change (IPCC) recommended values for the latest Emission factors.

Table 3: Emission factors marine fuels

(Source: MEPC Resolutions / 66th Session / Res.MEPC.245(66))

Type of fuel	Reference	Carbon content	C_F (t-CO_2/t-Fuel)
1 Diesel/Gas Oil	ISO 8217 Grades DMX through DMB	0.8744	3.206
2 Light Fuel Oil (LFO)	ISO 8217 Grades RMA through RMD	0.8594	3.151
3 Heavy Fuel Oil (HFO)	ISO 8217 Grades RME through RMK	0.8493	3.114
4 Liquefied Petroleum Gas (LPG)	Propane	0.8182	3.000
	Butane	0.8264	3.030
5 Liquefied Natural Gas (LNG)		0.7500	2.750
6 Methanol		0.3750	1.375
7 Ethanol		0.5217	1.913

For a duel fuel engine, different conditions apply. As stated in Res MEPC 282(70), if the correction factor is not available for any particular fuel, such as hybrid fuel, the supplier must provide a particular correction factor with sufficient evidence.

3.3.5.6 Determination of losses on quantity measurement of fuel

Determination of the quantities of fuels consumed are affected by the density and temperature. The correction for the density and temperature should be documented in the SEEMP Data Collection Plan which should be guided by the ISO8217 as stated in Res MEPC.282(70). The trim, list and vessel movements need to be considered when measuring the tank contents and estimating the fuel consumption.

To ensure the robustness, according to Res MEPC.282(70), of DCS and all losses are taken into consideration, the administration or the verifier must ensure the following:

- To ensure loses during transfer, separation and filtration have been taken into account and included in the SEEMP/MP,
- To ensure that accuracy factors for the fitted equipment in the fuel oil system is high and satisfies the administration,
- To eliminate data loss, standby equipment is available for quick replacement, and
- To carry out regular surveys on FO equipment on board.

3.3.6 Emission Report

The uniformed reporting can only be ensured by using the standardized template with no alteration of the fields (IMO, 2017). The electronic transfer of data from thousands of vessels have to be aligned and streamlined to a defined format.

Table 4: Standardized Data Reporting Format for DCS

(Source: Appendix 3: Res MEPC.282(70))

Method used to measure FO consumption	Fuel oil consumption (t)										Hours underway (h)	Distance Travelled (nm)	Power output (rated power) (kW)[8]		Ice Class (if applicable)	EEDI (if applicable) (gCO2/t.nm)	DWT[5]	NT[4]	Gross tonnage[3]	Ship type[2]	IMO number[1]	End date (dd/mm/yyyy)	Start date (dd/mm/yyyy)
	Method used to measure fuel oil	Other (...)	Ethanol (Cf: 1.913)	Methanol (Cf: 1.375)	LNG (Cf: 2.750)	LPG (Butane) (Cf: 3.030)	LPG (Propane)	HFO (Cf: 3.114)	LFO (Cf: 3.151)	Diesel/Gas Oil (Cf: 3.206)			Auxiliary Engine(s)	Main Propulsion Power									

In 2016 in Brussels, the EC published draft annexes, pursuant to regulation (EU) 2015/757 of the European parliament and of the Council on the monitoring, reporting and verification of carbon dioxide emissions from maritime transport consisting two parts which are:

a) Part A (Data Identifying the ship and the company) and b) Part B (Verification) The Particularities of the verifier, distance travelled, time spent at sea and transport work, energy efficiency (Fuel consumption, Average energy efficiency, voluntary second parameter of average, and differentiated energy efficiency for a laden voyage).

3.4 Comparison Between SEEMP and MRV Processes on the Data Reporting Requirements

The SEEMP will actually set the ground for IMO-DCS to be easily implemented on board ship. Both processes require continuous monitoring of the energy consumption. The IMO-DCS process gives responsibility to the Administration to verify the Monitoring Plan and ensure robust data being reported to the IMO's fuel consumption database for global stock taking. Additionally, the various data required for the calculation of EEOI are similarly applicable to the data collection process. The SEEMP and MRV processes both require dedicated responsible persons with specific duties in the monitoring plan. In the case of SEEMP, the EEOI is used as the primary monitoring tools where quantitative measurement for EEOI calculations is necessary (Regulation 22A of the MARPOL, Annex VI).

In Table 5 below, emission sources for monitoring fuel consumption are presented for comparison under the SEEMP, IMO-DCS and EU-MRV system.

Table 5: Emission sources under EEOI, IMO-DCS and EU-MRV System[8]

Sources of emission	IMO-SEEMP(EEOI)[λ]	IMO-DCS[φ]	EU-MRV System
Main Engines	√	√	√
Auxiliary Engines	√	√	√
Boilers	√	√	√
Gas Turbines	√	√	√
Inert gas Generators	√	√	√
Incinerator	X	X	√

[λ] All FO consumption onboard including listed in this Table.

[φ] All FO consumption onboard including listed in this Table

[8] Table 5 adopted from the guidelines MEPC.1/Cir684 for calculation of EEOI, IMO Resolution MEPC 278(70) and EU Regulation- (EU) 2015/757.

The organization should establish an Internationally recognized method for quantitative measurement of EEOI for the vessel and/or for the fleet. EEOI could be considered as the primary step for a vessel's energy efficiency monitoring (MEPC.213(63): SEEMP Guidelines). The tools, concepts and methods of monitoring the energy efficiency data should be decided in the planning stage and mentioned in the SEEMP (Korean Register of Shipping, n.d.).

Table 6: Comparison of SEEMP, IMO DCS and MRV data

Scope	EEOI	IMO DCS[α]	EU MRV
Nature of implementation	Voluntary	Mandatory	Mandatory
Applicable to	>=5000	>5000	>=5000
Monitoring and Verification	In house	3rd party	3rd party
Ship particulars	√	√	√
Fuel consumption at sea	√	√	√
Fuel consumption at berth	√	√	√
Time spent at sea	√	√	√
Distance Travelled	√	√	√
Cargo on-board	√	√	√
Transport work	√	√	√
Energy efficiency parameters	NA	√	√
Emission Factors	√	√	√
Ballast Voyages	X	√	√
Number of voyages	√	X	X

[α] All aggregated data for fuel consumption need to report to IMO

The SEEMP and MRV processes go hand-in-hand as the goals and a significant part of the SEEMP coincide with the MRV process on maintaining data for fuel consumption to monitor the EEOI.

3.5 Summary

This chapter provides an insight of the MRV system in the shipping industry. A comparative picture of the IMO-DCS and EU-MRV gives a better understanding of regulatory compliance while the comparison between the elements of existing SEEMP and the MRV gives a view on current status and inadequacies towards implementation of the MRV system. The structured presentation of both the MRV system and discussion on fuel consumption monitoring methods and losses can provide a deeper understanding to identify barriers, gaps, and issues with the data collection process.

Chapter IV

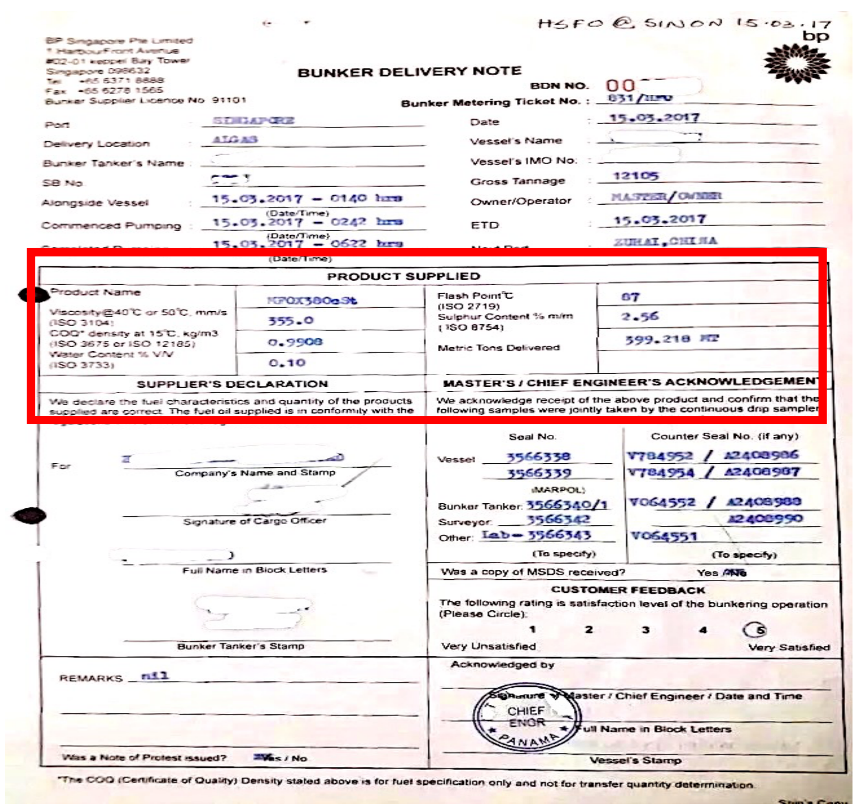
Existence of Potential Data Error

4.1 Overview

This chapter highlights the source of potential data errors in some of the elements of the fuel consumption monitoring methods, equipment and documentations. Each element has been analyzed and specific errors within these elements are identified and discussed.

4.2 Bunker Delivery Note

A Bunker Delivery Note (BDN), in Figure 8, includes the information regarding fuel bunkered with the BDN, such Product name, the viscosity at 40^0C or 50^0C (mm/S), Certificate of Quality (COQ), the density at 15^0C (Kg/m3), the water content 0.10% (v/v), Flash Point 87^0C, Sulphur Content 2.56% and the metric tons delivered.


HSFO @ SINON 15.03.17

bp

BP Singapore Pte Limited
1 HarbourFront Avenue
#02-01 Keppel Bay Tower
Singapore 098632
Tel +65 6371 8888
Fax +65 6278 1565
Bunker Supplier Licence No 91101

BUNKER DELIVERY NOTE

BDN NO. 00

Bunker Metering Ticket No. : 831/HFO

Port	SINGAPORE	Date	15.03.2017
Delivery Location	AIGAS	Vessel's Name	
Bunker Tanker's Name		Vessel's IMO No.	
SB No		Gross Tannage	12105
Alongside Vessel	15.03.2017 – 0140 hrs (Date/Time)	Owner/Operator	MASTER/OWNER
Commenced Pumping	15.03.2017 – 0242 hrs (Date/Time)	ETD	15.03.2017
Completed Pumping	15.03.2017 – 0622 hrs (Date/Time)	Next Port	ZUHAI, CHINA

PRODUCT SUPPLIED

Product Name	MFOX380cSt	Flash Point℃ (ISO 2719)	87
Viscosity@40℃ or 50℃, mm/s (ISO 3104)	355.0	Sulphur Content % m/m (ISO 8754)	2.56
COQ* density at 15℃, kg/m3 (ISO 3675 or ISO 12185)	0.9908	Metric Tons Delivered	599.218 MT
Water Content % V/V (ISO 3733)	0.10		

SUPPLIER'S DECLARATION

We declare the fuel characteristics and quantity of the products supplied are correct. The fuel oil supplied is in conformity with the

For ______ Company's Name and Stamp

Signature of Cargo Officer

Full Name in Block Letters

Bunker Tanker's Stamp

MASTER'S / CHIEF ENGINEER'S ACKNOWLEDGEMENT

We acknowledge receipt of the above product and confirm that the following samples were jointly taken by the continuous drip sampler

	Seal No.	Counter Seal No. (if any)
Vessel	3566338	V784952 / A2408986
	3566339 (MARPOL)	V784954 / A2408987
Bunker Tanker	3566340/1	V064552 / A2408988
Surveyor	3566342	A2408990
Other	Lab – 3566343 (To specify)	V064551 (To specify)

Was a copy of MSDS received? Yes /No

CUSTOMER FEEDBACK

The following rating is satisfaction level of the bunkering operation (Please Circle):

1 2 3 4 (5)

Very Unsatisfied Very Satisfied

REMARKS nil

Was a Note of Protest issued? Yes / No

Acknowledged by

Signature of Master / Chief Engineer / Date and Time

CHIEF ENGR PANAMA

Full Name in Block Letters

Vessel's Stamp

*The COQ (Certificate of Quality) Density stated above is for fuel specification only and not for transfer quantity determination.

Figure 8: Sample of BDN

In this particular example, Figure 8, the fuel contains 0.10% of water at delivery which is treated and removed by the purifier in a later stage. The total quantity supplied is about 400 metric tons; therefore, the total water content of the fuel oil is 400 liters. In accordance with the ISO 8217 standard, water content can be up to 0.5% v/v for this type of fuel. For all marine residual fuel, water content can differ from 0.3 to 0.5% v/v and for distillate fuel as high as 0.3% (ISO, 2017). Other impurities in fuel oil are not mentioned in the BDN and will only be revealed through the laboratory analysis report.

According to the above BDN the specified fuel is of MFO380cst. Limits of impurities of the fuel oil are defined as per ISO 8217 for the above type of oil as represented in Table 7.

Table 7: ISO8217 Fuel specification

(Source: Adopted from Shippedia, 2017)

Impurity Parameter	Unit	Limit	RMG	Impurities in One ton (KG)
Micro Carbon Residue	% m/m	Max	18	
Aluminum + Silicon	mg/kg	Max	60	0.06
Sodium	mg/kg	Max	100	0.1
Ash	% m/m	Max	0.100	1.00
Vanadium	mg/kg	Max	350	0.35
Water	% V/V	Max	0.50	5.00
Total Sediment, aged	% m/m	Max	0.10	
Used lubricating oils (ULO): Calcium and Zinc; or Calcium and Phosphorus	mg/kg	–	The fuel shall be free from ULO, and shall be considered to contain ULO when either one of the following conditions is met: Calcium>30 and zinc >15; or Calcium > 30 and phosphorus > 15.	0.04
Hydrogen sulphide	mg/kg	Max	2.00	0.002
Sulphur	% m/m	Max	Statutory requirements	

If the maximum presence of impurities is considered in one ton of fuel oil, in accordance with the above parameters, the quantity of impurities will be 6.56 Kg/Ton (Maximum) which is 0.656%. These impurities are separated by the settling and purification process. Effective separation of impurities depends on the setting and operational parameters of a purifier. A small quantity of fuel is discharged through a sludge discharge cycle of a purifier under the normal operating condition which depends on the frequency of the sludge discharge cycle, the amount of impurities in oil, and the capacity of purifier bowl. FO purifiers are normally set for sludge discharging at every 2-hour cycle (according to manufacturer manuals or Chief Engineers instructions). Thus, estimating as less as 2 liters of oil is discharged during each desludging operation, considering the throughput of a FO purifier is 3000 Liters/hours, approximately 0.033% oil is lost through the separation process. Therefore, in this case, a total quantity of 0.69% of FO deduction from the bunker quantity due to impurities in the FO (quality of RMG) may be considered for the calculation of FO loses. Again, a certain quantity of FO is lost with the filtration and draining of the fuel oil system which is considered negligible here.

4.3 Shortage of supply to ship during bunkering

To ensure exact quantity received during bunkering is a challenging task for ship's crew. In reality, the supplier's quantity may be claimed higher than the vessel's measured quantity. Declaring FO temperature less than the correct temperature, higher density, the cappuccino effect, injecting excessive water, falsifying soundings, delivering excessive quantity of solid sludge, are among many ways of how the bunkered fuel amount can be "cheated" during the bunkering operation. Ship's crews often discover the shortage later when the BDN is signed. By that time, it is too late to recover the shortage. Sometimes, the entire process is so complicated that ship's crew is tempted to adjust the short quantity by declaring more consumption during the part of their voyage or adjust from a previously undeclared quantity in hand. Occasionally, a significant amount of BDN quantity is lost due to fraudulent act of supplier to the vessel. From the expert's opinions on the bunkering operation, it can be estimated that a 5 ton of FO quantity mismatch is common for a 500 tons FO bunkering. Therefore, according to the above about 1% of oil from the BDN quantity falls short due to misconduct in the bunkering process. However, this it varies from country to country and port to port. Therefore, from expert's opinion, it is suggested that the quantity mismatch or data error in this case will be about 1.69% (Source: Estimation from the content of impurities in oil according to ISO8217 and short supply during bunkering).

4.4 Error with Measurement of Bunker Tank

Besides maintaining the stability of ship, voyage planning, cargo planning, assessing leaks in the tanks, sounding of the fuel tanks are necessary for quantity measurement to determine the fuel consumption and stock assessment everyday (Marine insight, 2017). Manual soundings of the fuel tanks are the most common for assessing the tank content. The accuracy of the measurement by manual soundings is considered erroneous as it depends on various factors such as the stability condition of ship, shape of tanks and trueness of sounding pipe, measuring tape, knowledge of the person performing the task as well as state of sea, as a vessel's movement can cause erratic and wrong readings. Looking at the technology use, the bubbler type of level gauges is widely used for the measurement of bunker tanks. In many ships, the capacitance-type level gauges and electrically-powered servo operated gauges are also used. However, a certain degree of error exists with all these devices used for tank level measurements. Regular calibration and testing of the tank monitoring devices is necessary for reducing the error margin. Moreover, during the storage and treatment of various processes such as evaporation, filtration and purification of the fuel oil, this could produce a mismatch of the quantity which actually gets consumed in the engine and poses about 0.69% (as described in section 4.1) of the fuel oil loss in the process. Two or more gauging systems are employed simultaneously to ensure accuracy and reduce wrong soundings.

4.5 Flowmeter as a Source of Error

Fuel oil flow meters are installed adjacent to the engine in the circulation lines, inlet and outlet; this system is known as the "differential measurement" as a deduction of the outlet value from the inlet gives the engine consumption directly. These flow meters have to be reliable and work in a high temperature of 150^0C to 160^0C with pulsating piping connections. The engine-specific fuel consumption data can be fed into the necessary database (KRAL, 2017). There are many types of flowmeters are on the market with a wide range of accuracy. Some manufacturers claim to achieve high precision as close as 0.1% error margin. However, the error has to be checked and certified and in the case of implementation of MRV, this has to be verified by the accredited verifier during approval of the Monitoring Plan.

Figure 9: Marine Fuel Oil Flow meter, Source: KRAL

In accordance with the IMO, NOx technical code fuel consumption monitoring devices permissible deviation could be ±2% of the engine's maximum value (IMO, 2017). To ensure data accuracy and efficient collection and storage of data, vessel operators need to ensure installations, regular calibrations and maintenance of the flowmeter to be carried out as per the regulations.

4.6 Error with Exhaust Gas Uptake Measurement Devices:

The exhaust gas emission of the CO2 measurement is applicable to the EU-MRV system where probes fitted on the exhaust uptake of engine directly measure the quantity of CO2 emissions for a particular time period. Some manufacturers for this instrument provides a real time online monitoring system which gives the operator one stop solution for data collection, storage and reporting software and multiple communication options.

According to the Figure 10, ship's data transferred to vessel's head office via communication satellite using Modem, and GSM, GPRS systems and shared with the service providers.

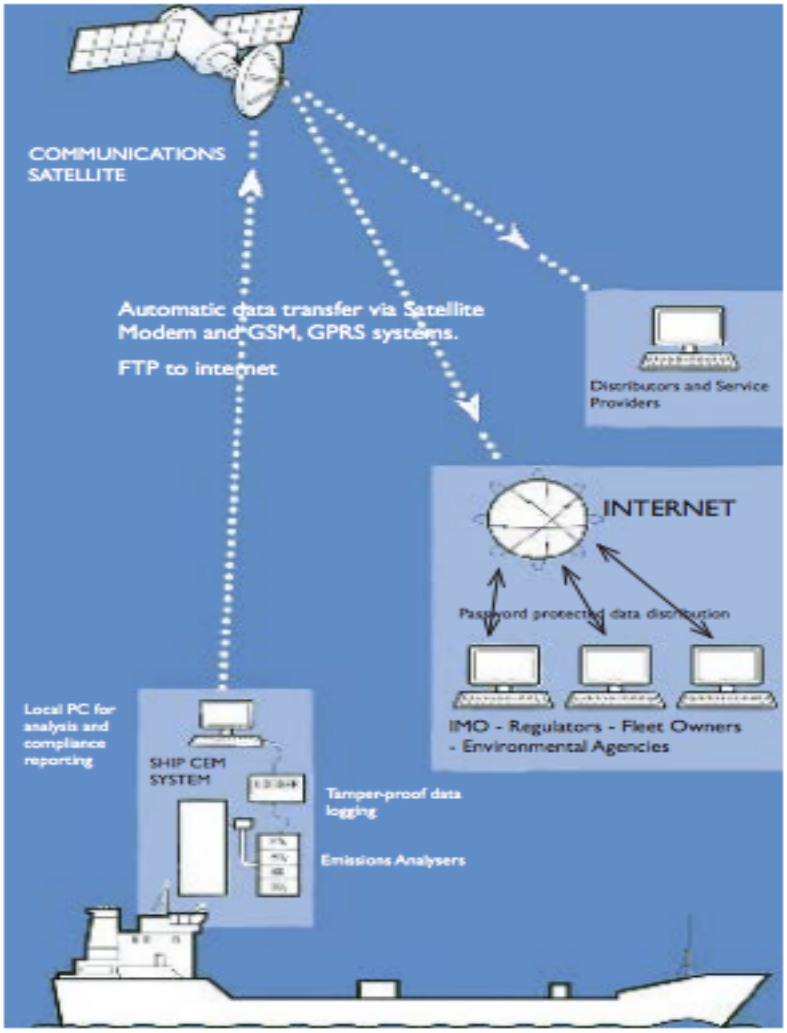


Figure 10: Data exchange process for Exhaust Gas Monitoring Device, Source: Consilium

According to the NOx technical code, the exhaust gas flow measuring monitoring instrument permissible deviation could be $\pm$2.5% of the engine's maximum value (IMO, 2017).

4.7 Documentation for Recording Fuel Consumption

A vessel's Engine Log Book and Chief Engineer's Log Abstract are two important documents which are used to record fuel consumptions and the necessary relevant information for a ship's daily activities. The information stored in these documents aid the fuel consumption calculation and could be fed into a data collection system of the MRV. Therefore, to enhance the effectiveness of the MRV process, understanding the requirement and availability of information of resources is extremely necessary. Thus, eliminating the errors from the use of conventional Engine room log book and Chief engineer's log abstract could aid the implementation of MRV process.

4.7.1 Engine Room Log book

The Engine Log Book is an important legal document which is maintained on board ship with utmost care as daily activities are recorded in a log book. As per the International Safety Management Code (ISM), a log book needs to be stored for five years. A responsible marine engineer watch-keeper needs to fill up the log book diligently in his/her watch to record machinery operational parameters, fuel oil and lubricating oil flowmeters readings, various tanks' daily soundings and the instructions and maintenance are entered in-brief on daily basis. Snapshots of all the activities onboard a ship are available in the Log book which is a great tool for the assessment of the engine performance. It is necessary to analyze the contents of the log book for data related to the MRV for the further integration of the collection of relevant data for effective implementation and analysis of the gap in data collection. The accuracy of the data depends on the person involved, however, it remains as a source of inaccurate and fraudulent data. The highlighted portion of the log book pages and parameters in Appendix 2 represent relevant parameters which are used for the calculation of fuel consumption for the MRV process. The main and auxiliary engine running hours, FO temperature, FO consumption, FO tanks' sounding for quantity retaining on board, include distance travelled and time under way, for the ''cargo quantity carried'' which is not entered in the engine log book.

4.7.2 Chief Engineer's Log Abstract

The Chief Engineer's Log Abstract (CELA) is a document representing voyage information and related static and dynamic data. The relevant information related to the fuel consumption calculation in this document are date and time, event, mode of operation, vessel status, main engine revolutions, distance travelled by engine and ship, fuel oil consumption and the remaining on board and other miscellaneous information maintained by chief engineer. In some ships, this information is based on the events as they occur and data collected are stored in an excel sheet and sent to the vessel's head office for monthly internal record keeping. These are also used for calculation of vessel's environmental performance and calculation of EEOI. The CELA is not mandatory through any legislation, however, it is a longstanding practice by the industry to track a vessel's operational dynamic and stationary data in every occasion as they occur. A recent copy of the vessel's CELA, maintained by an anonymous company, is added in Appendix 3 of this paper. Reading the provided information in Appendix 3, it is evident that the data required for MRV could be extracted from this document. It is also apparent that the ship's crew has to insert the same data in several places on every occasion; as noted that Engine Room Log Book and CELA contains exactly the same information in many cases, especially regarding the data related to MRV. This repetition can be eliminated by introducing efficient processes of data collection. However, the vessel's owner has to prove to the verifier the authenticity and reliability of data what will be reported to the MRV database. The manual input of data and transmission in the company's specified non-standard format poses the risk of fraudulent tampering and manipulation of the data.

4.8 Summary

An accurate and reliable source of data is the foundation for an effective MRV system. The existence of errors in the instruments of the MRV process can be considered as barriers to the effective implementation of the system. The errors with the fuel consumption monitoring equipment, such as fuel tank measuring devices, flowmeters and exhaust gas outflow measuring devices can be eliminated by integration of new technology with high precision. Again, existing errors with the BDN and short delivery of the bunker can be encountered by the better policymaking, regulatory compliance, and technological improvement. Analysis of the sources emphasized the scope of potential improvement to eliminate data errors and ensure smooth implementation of MRV system.

Chapter V

An Evaluation of the Shipping Industry's Readiness to the MRV

5.1 Overview

A survey question describes more as it is not a general inquiry. The attitude, attributes, behavior, and belief of each respondent could be determined by the sample of survey questions by the surveyor which also serves as a tool for the surveyor (Dillman, 2007). Answers of the questions in the questionnaire help to diagnose or reach in a decision on the basis of the outcome. The principle motivation of the survey was to reveal the potential barriers, gap and industry's standpoint with regards to the implementation of the upcoming shipping MRV regulations of the IMO and EU. As such, the survey was divided into five groups: *General, Policy, Technological Standpoint, Human Perspective* and *Ensuring Data Quality*. Each section was customized with a limited number of questions, maintaining simplicity, cohesiveness, focus, and depth of the question towards finding the situation of the industry without compromising the quality of the questionnaire. This survey's questions were carefully constructed to understand the present status of the shipping industry with respect to energy efficiency, determining the barriers for the implementation of the MRV.

5.2 Discussion on Questions of the Survey Questionnaire

5.2.1 Group A: General

In this section recipients were asked some general questions about themselves to assess the credibility, validity, reliability and weight of the answers provided by them. The questions were asked to reveal their position in shipping sectors, age, gender and academic qualifications.

The survey questionnaire was distributed among persons related to shipping industry through Google form from 14 June 2017 to 21 July 2017, and a large number of participants have been registered during that time. A total of 74 persons have participated the survey, with their full consent, all the questions of the questionnaire and submitted via Google form. Among all, 90% are male and the rest (10%) are female with diverse maritime backgrounds, such as Navigating Officers (n=13, 17.81%), Ship's Engineers (n=32, 43.84%), Maritime Administrator (n=6, 8.22%), Ship Managers (n=11, 15.07%), Port Officials (n=3, 4.11%), Maritime Education and Training providers (n=2, 2.74%), Classification society surveyors (n=2, 2.74%), Pilots (n=1, 1.37%), Marine Surveyors (n-1, 1.37%), Flag administrators (n=1, 1.37%) etc. The demographic profile of the participants displays that all participants are in middle or later stage of their career, which a degree of reliability, validity, and credibility of the responses is reasonably guaranteed. None of the participants were below 25 years of age; 50% are between 35 and 45 years; over 66% of them are more than 35 years; and 16% are more than 45 years of age. Moreover, it was evident that many participants possess high educational qualifications as 40% are with Masters' or above, 47% Bachelor's degrees, and the rest was either Master mariner or Certificate of competency (Class 1) holders.

5.2.2 Group B: Policy Perspective

(How are the shipping companies getting ready, setting up policy and strategy, prior kicking off IMO's Data Collection System (MARPOL ANNEX-VI, Reg-22A) and EU MRV (Reg. 2015/757) System?)

Operational and compliance issues ISO (International Organization for Standardization) is a global organization for standardization which sets standard for various discipline. ISO 9001, ISO14001 and ISO50001 are very important for shipping companies to operate with excellence and reputation. Recently many shipping company subscribe to the standards for goodwill, reputation and profitability. Any company subscribing to these standards will have better system in place and will face less hindrance implementing MRV regulation.

As in the Figure 11, highest number of persons have selected ISO 9001:2015 for company's quality management system; organizations complying this standard are able to provide its customers quality services continuously (ISO, 2017).

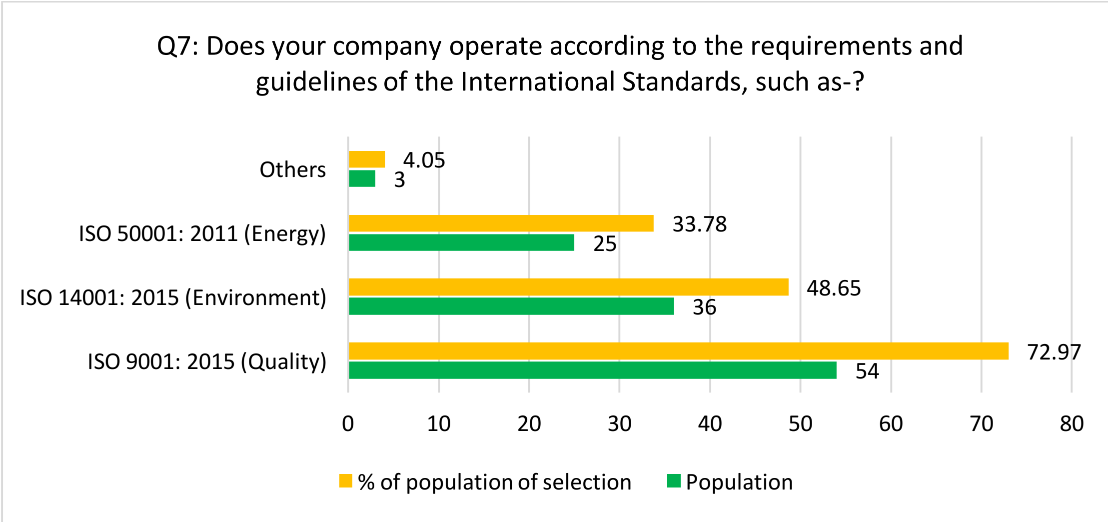


Figure 11: Use of international Standard in a company

About 49% of the respondents' organizations meet the ISO14001: 2015 (Environmental management) standard; the organizations activities are monitored, controlled and environmental impacts are minimized by complying this standard. Energy Management System standards, ISO 50001:2011 is still making way into the industry as 34% of respondents' organization are meeting this standard. Others are involved with IMO regulation or ISM regulations, where none of these International standards are followed which constitutes about 4% of the population.

ISO50001 requires organizations to monitor, measure and analyze their energy performance at planned interval (ISO, 2017) which could be a perfect platform for easy implementation of MRV system. Therefore, we could see that energy management system still need to be adopted in a great extent by the shipping sectors.

Recently, many reputed companies have prioritized Energy efficiency and importance has given to energy management system, it is even Energy efficiency as their corporate goals and objectives beside health, safety security and environment equally. These organizations are frontrunner and will have easy adoption of MRV system. In this question, it was possible to select multiple answers and respondents given their opinion as below.

Institutional issues Energy efficiency became a matter of great importance in the maritime industry, as about 55% of the respondents have stated that Energy efficiency is included in their quality management system. A step ahead, about 35% of the respondents' organizations have incorporated in corporate goals and objectives.

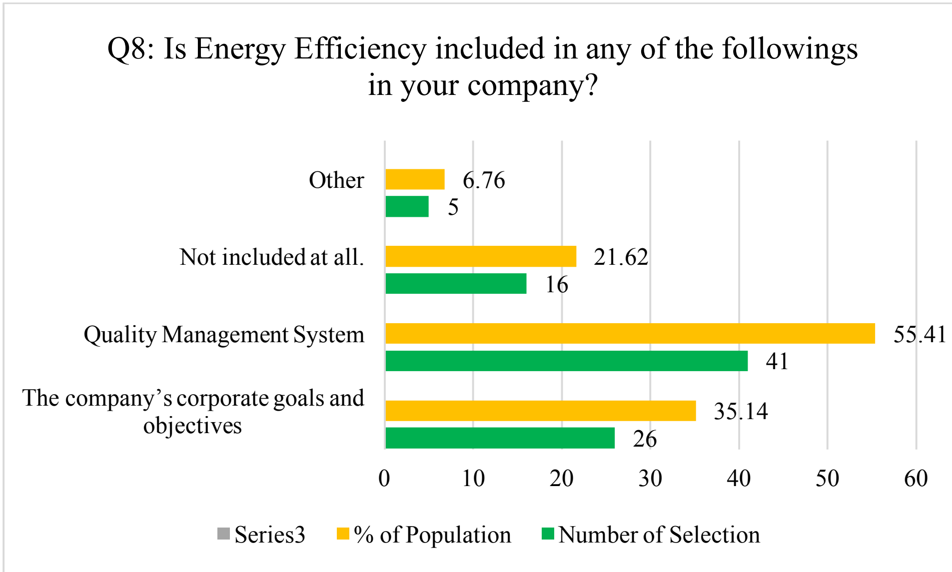


Figure 12: Inclusion of Energy Efficiency Measures

About 7% of the population mentioned that the Energy efficiency measures exist in their organizations as SEEMP as cost effective measures. However, a significant number, about 22%, mentioned that the Energy efficiency is not included in their organization in any form. These organizations will face as they will lack in policy, organization structure and developing framework for implementation of Energy efficiency measures as well as MRV system.

Management Issues Having a dedicated Energy Management Team will ensure companies all energy related issues to control efficiently with better monitoring capability. The ability of data collection, storage and analysis will be enhanced which will also create a smooth pathway for adoption of MRV system.

In this study, it is observed that about 44% of the respondents mentioned that dedicated energy management team exist in their organizations where 55% mentioned that no separate energy management team exists in their company.

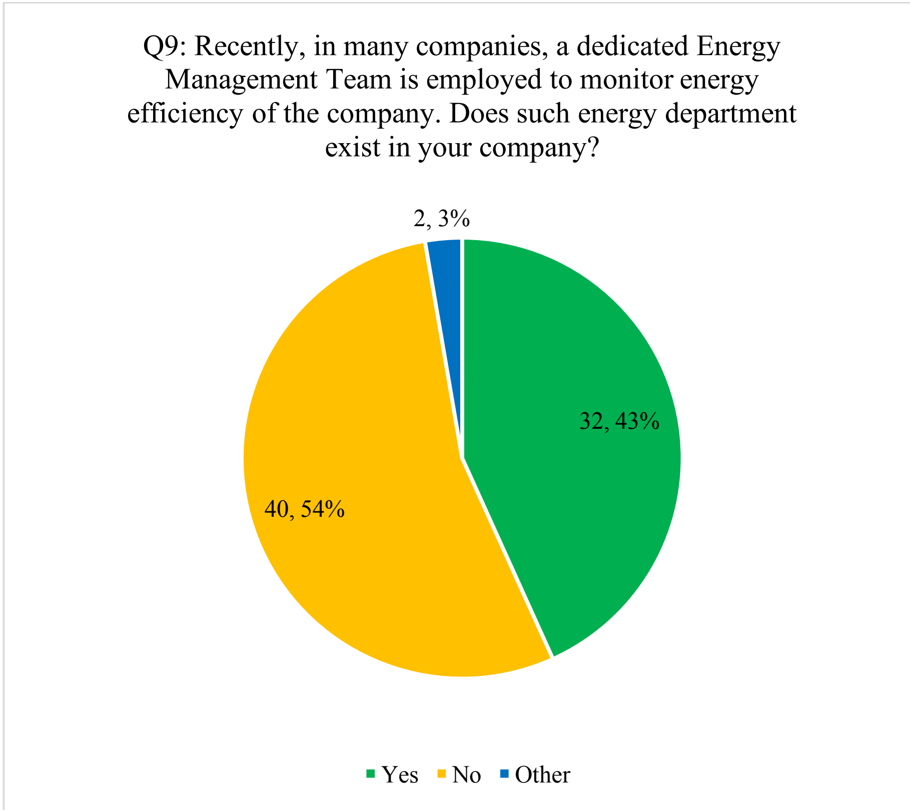


Figure 13: Existence of Energy Management Team

The above Figure 13 displays a lack of corporate commitment to maintain Energy efficiency a priority. Some company may get energy management tasks dedicated to employees on-board or on-shore monitoring purposes, however, to reduce the workload on ship personnel and better monitoring a dedicated energy management team in necessary to enhance Energy efficiency further. Therefore, lack of commitment to adopt Energy efficiency policies in organizational level is so far evident here.

Preparedness for MRV Monitoring, Reporting and Verification (MRV) System is a mandatory process for both IMO and EU. EU requires Ship Specific Monitoring Plan to be approved by the authorized verifier not later than 31 August. 2017. Thus, many companies are working towards development and approval of the monitoring plan by the verifier.

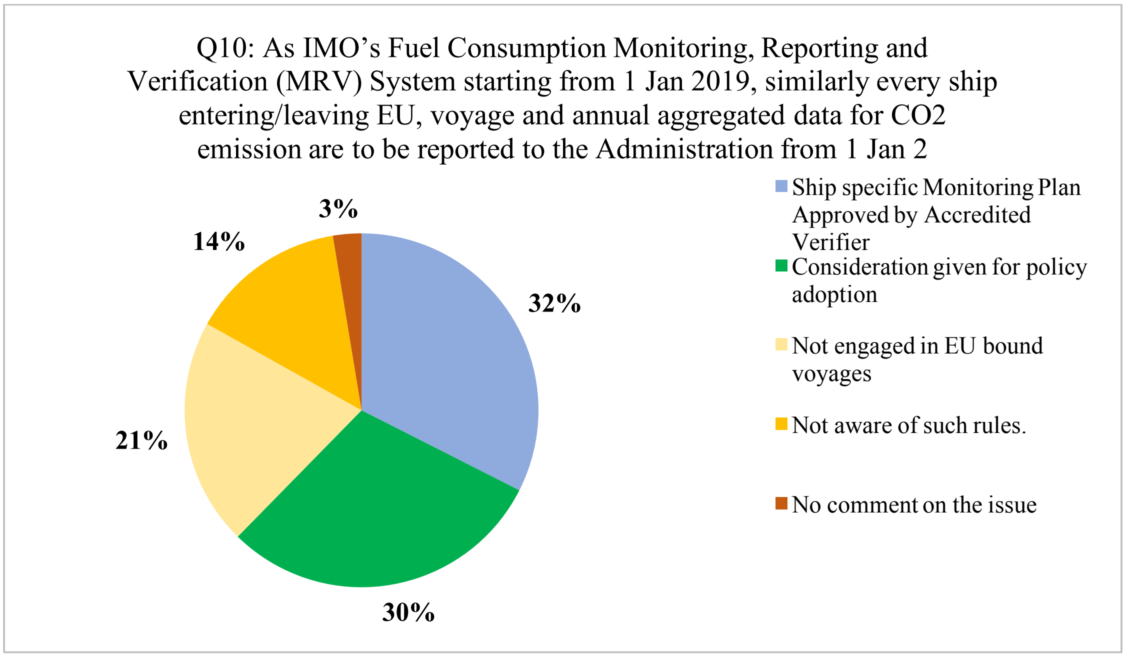


Figure 14: Applicability of EU-MRV System

As much as 34% of the respondents mentioned that the Ship Specific Monitoring Plan have been approved by the verifier and more than 31% said that adoption of the policy for implementation of the MRV regime and process in progress for EU going vessel. Thus, 65% of the organizations are in the process of adopting MRV. This is considered as significant number of population. The population of 22% stated that the vessels are not engaged in EU bound voyage, they require to abide the timeline of IMO's data collection regime. However, a significant portion of the organizations under this study are not fully ready to commence with MRV, considering 31% for "consideration given for policy adoption".

Impact of MRV on SEEMP According to MARPOL Annex VI Regulation 22A, monitoring plan of the data collection system has to be incorporated in the SEEMP and approved by the verifier. All details of the system have to be endorsed in the SEEMP. Moreover, many existing procedures and data of SEEMP are relevant and required by DCS too. Thus, it is necessary to know how these will interact.

In this survey, as much as 73% of the respondents believe that introduction of MRV will affect SEEMP positively to a great extent. Over 24% believes that the MRV will have minor positive impact on the SEEMP or Energy efficiency as a whole.

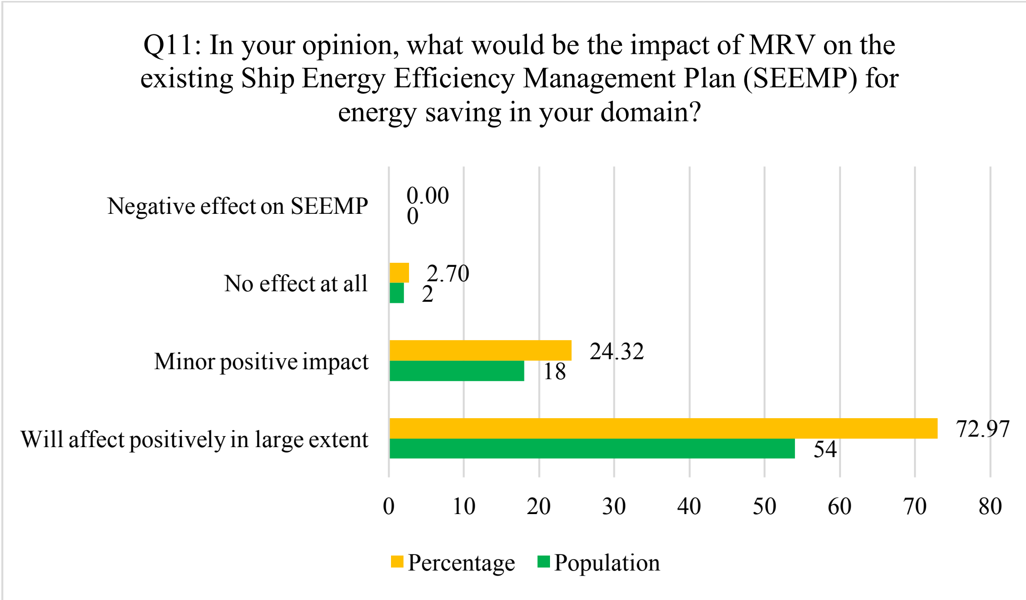


Figure 15: Impact of MRV on SEEMP

Therefore, over 97% of the respondents believe that the MRV will have some positive impact on the SEEMP and improvement of Energy efficiency on board ship. Again, no one believes that I will have a negative impact on SEEMP. The Figure 15 shows that the people are having positive mindset and expectation about the MRV system which will help to ensure effective implementation of MRV in future. Moreover, emergence of MRV will aid and enhance ship's Energy efficiency process and promote future greener policy making more realistic and robust data supported.

5.2.3 Group C: Technological Standpoint

(What are the existing technology gap for proper implementation of MRV process in shipping?)

Technological options MRV require annual disclosure of aggregated data which is monitored per voyage and annual basis. Real time online fuel consumption monitoring device facilitates MRV anomaly detection and provide ability for early detection and arising risks correction. Real time monitoring also eliminates data gap as it is collected over long period of time in different occasions.

Installation of real-time online fuel consumption monitoring devices for effective implementation of MRV, seems as good as other solutions to 55% of the respondents.

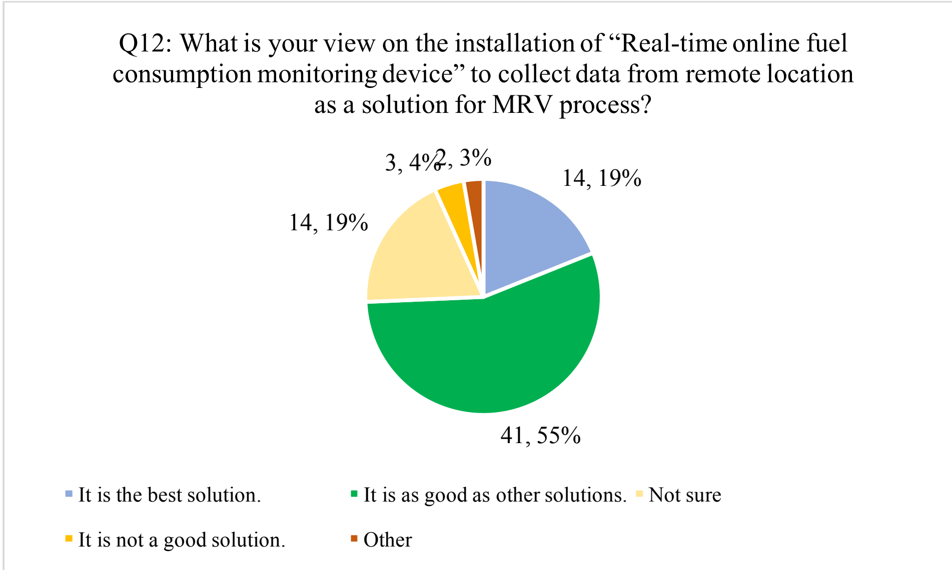


Figure 16: Fuel consumption monitoring system

About 19% percent thinks that to install real time monitoring device is the best solution for proper implementation of MRV process, Similarly, 19% also not sure about the technology adaption preferences whereas 4% thinks that this is not a good solution. Two respondents given their opinion differently as one said "For sure it is expensive equipment to install and no guarantee for effectiveness. As such equipment will be bound for regular calibrations, maintenance, etc." and other said "It will best if challenges such as data security, and means of verification will be overcome". In this context, it is clear that people are quite skeptical about the outcome of real-time data monitoring devices, however, prior installation of such devices, it is necessary to examine the applicability, redundancy and reliability of such systems and certified by approved authority.

Choice of methods of fuel consumption monitoring Fuel consumption monitoring methods have significant influence on the data collection system, as it is a vital part of the MRV system and adopted method has to be defined in the monitoring plan and approved by the verifier. Method A, B and C are applicable to IMO-DCS and all fours are for EU MRV system.

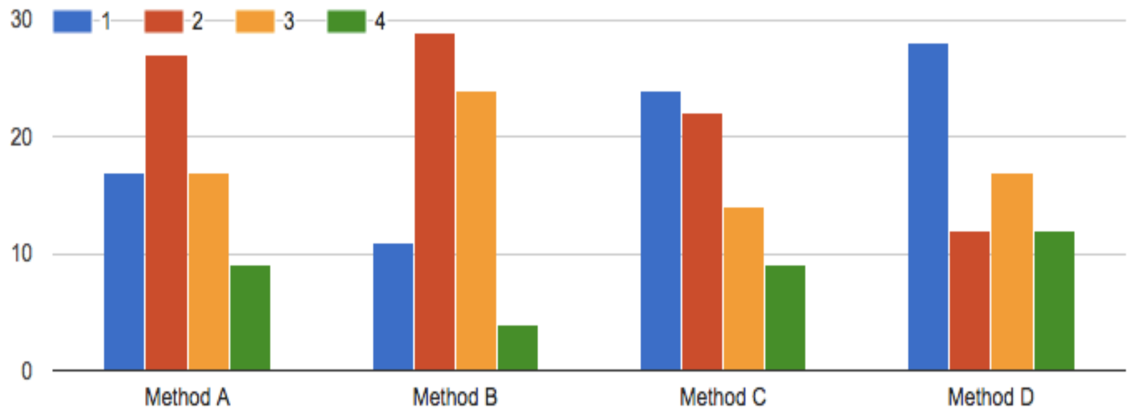


Figure 17: Evaluation of Fuel Consumption Monitoring Method

According to the reading obtained from the survey, calculation of ranking is as below:
For method A, 1 was selected for 17 times which makes 1X17=17 points, similarly, 2 for 27 times, 3 for 17 times. Every position was multiplied by their number of hits and addition of all gives the aggregated value for the method A is 158.

Method A=(1X17) + (2X27) + (3X17) + (4X9) = 158

Method B=(1X11) + (2X29) + (3X24) + (4X4) = 157

Method C=(1X24) + (2X22) + (3X14) + (4X9) = 146

Method D=(1X28) + (2X17) + (3X17) + (4X12) = 151

In this case, the lowest value gives the most preferable method for fuel consumption calculation. Therefore, the rating of preference for the fuel consumption monitoring is as below order, Method C, Method D, Method B and Method A respectively.

The conventional method of calculation of fuel consumption through flowmeter reading still stands as the first preference over others. Method D: Direct measurement from the exhaust stack is at the second choice. However, this is not very common and rarely seen used on board ship which will also require new installation. This will reduce burden of seafarer of manual data collection and logging. Method A: BDN and periodic stocktaking is the least preferred method, despite, which will require less capital investment on equipment installation and considered as less complicated method.

Logging methods Mode of input is an influencing factor for data quality. Using Auto-logging system with sensors could provide faster response and be useful for anomaly detection, therefore, reducing the deviation.

The study shows that the manual data logging at every 24-hour basis, preferably with the noon report is a well adhered mode of data collection, as this process is followed by most of the ships and 53% of the population involved in this study selected it as their existing method for data collection, however, auto-logging with sensors are also showing more acceptance as about 37% respondent are having this system on board where data is collected remotely with minimum human interaction.

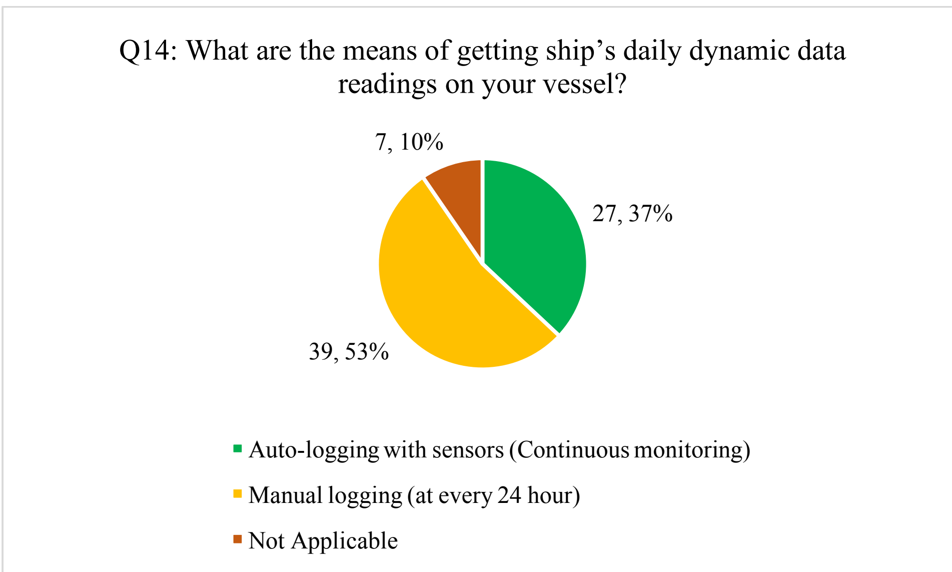


Figure 18: Ship's daily dynamic data

The degree of accuracy of the instruments depends on the error margin and correctness of the equipment. Where in case of manual logging it is solely dependent on the persons involved in the process. Although, less interaction of human causes less chance of error taking reading and smooth transition of data without much hindrance. Seven people have chosen "Not Applicable" as their works are related to Maritime administration, thus, not directly related to vessel's operation.

Data quality issues Data collection procedures, verification and automation are all influencing factors for maintaining data quality of MRV system. Analyzing the influencing factors could facilitate further actions and enhancement of data quality.

Table 8: Survey Outcome of Question 15

Factors for Data Quality Improvement	Population	Percentage
Improved collection procedures and management	30	40.54
Auditing regime	9	12.16
Improved automation (installing sensors)	33	44.59
Other	2	2.70

According to the result of the survey, improved automation and better data collection procedures are two most influential factors for data quality.

The above Table 8 represents improved automation by installation of sensors for data collection and transmission will have the quality data with less error, as agreed by 45% of the respondents. Again, about 41% of the respondents advocate for the improved collection procedures and management for getting quality data. About 12% of the respondents believe that the auditing regime could improve the data quality. However, this study shows that the improvement of vessel's automation is the top most priority to have the quality data for MRV.

Compatibility for MRV Prior verification of monitoring plan every ship needs to be assessed on various criteria such as compliance, technological ability, data collection, transmission, procedures and resources. Assessment could be carried out by internal or external experts to ensure proper compliance.

Table 9: Survey outcome of Question 16

Assessment for MRV	Population	Percentage
Assessed by Internal experts	21	28.38
Assessed by External MRV service provider	14	18.92
Status not assessed	24	32.43
Not Applicable	9	12.16
Empty	6	8.11

About 19% of the population had their vessel *MRV-Ready assessment* carried out related to technological requirements by the external verifier. It is not significant quantity, however, many of the ships are not sailing on EU bound voyages and IMO-DCS will be implemented on 1 January, 2019, there are a few months left for Non-EU bound vessels to get ready for compliance for mandatory IMO-DCS.

Highest number of respondents, about 32%, did not have vessel's technological status assessed by the internal or external verifier. More than 28% of respondents stated that their technological status for MRV implementation requirement on board ship have been assessed by the internal experts. About 20% of the respondents replied as "Not applicable" and "No comment'' on the issue due to their works are not directly related to vessels' operation.

5.2.4 Group D: Human Element

(What is the status of expertise, knowledge and awareness of ship's crew on correct data feed, monitoring, reporting and verification requirements?)

Awareness of MRV process Awareness is the precursor for compliance. To ensure proper compliance to any regulations all personnel involved in the process need to be fully aware about the requirements of certain process. Therefore, it is necessary to know the level of awareness about MRV in shipping sectors.

Awareness comes with training, briefing, knowledge sharing with other persons prior involvement with activities related to certain rules. In this case, company shall ensure any regulatory development in the industry heralded and information are disseminated among employees.

According to this study, 68% of the respondents are aware of the upcoming MRV regulations and development in IMO and EU and about 4% of the population are aware about the MRV in some extent.

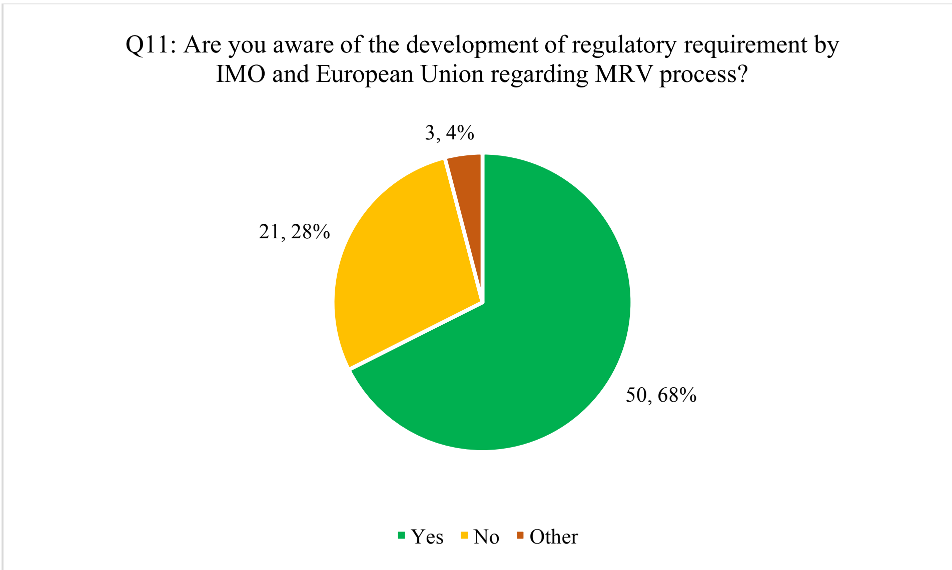


Figure 19: Awareness of EU-MRV

However, more than 28% of the respondents are not aware of the development. Implementation of MRV in shipping industry is a significant taken by IMO and EU to measure the shipping emission which could lead to future Market-Based-Measures for the industry. Therefore, organizations shall carry out training to educate employees to ensure better data management in future.

Personal availability According to Resolution MEPC.213(63), company shall ensure tasks are defined and dedicated to competent personnel to carry out the tasks of implementation of SEEMP. Data required by voluntary EEDI is similar to the required data under MRV system. Thus, if persons are educated on SEEMP, he would be beneficial for implementation of MRV system.

According to this survey, half of the population stated that they have designated specific duties under SEEMP as they are directly related to the vessels, 44% does not have duties as per SEEMP and 5% of the population are not aware of such measures. Ship's engineers and navigating officers are involved in this survey are directly related to SEEMP, however, others have different job profile.

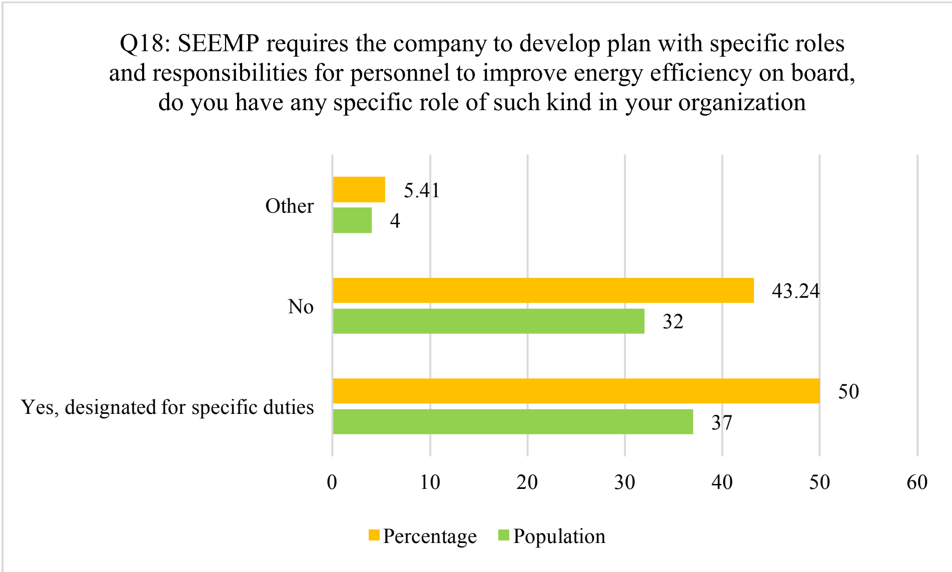


Figure 20: Responsibilities under SEEMP

Training needs SEEMP is a process of self-evaluation and improvement, requires in-depth knowledge on vessel operating profile, operations, planned maintenance and technological support for fuel efficient operation. Efficient operations are ensured by trained and competent employees and they are also considered as a support for implementation of MRV program.

Table 10: Survey Outcome of Question 19

Types of Training	Population	Percentage
In-house training sessions as per SEEMP	33	44.59
Customized training by External experts or institution	12	16.22
Not participated any training about Energy efficiency	15	20.27
Other	14	18.92

In this survey, a high number of persons underwent some sort of training on Energy efficiency, among them 45% attended in house training, 16% attended customized training by External experts or institution and above 8% extensive training on both customized and in-house training on Energy efficiency.

About 19% had different opinions about the topic as some stated that senior officers are briefed during pre-joining briefing, superintendent's ship visit and some of the organizations have sent respondents to the World Maritime University, Malmo, Sweden to gain expertise on Energy efficiency for their organization. However, more than 20% of the respondents did not participated Energy efficiency training, therefore, it can be considered as significant number of people lacking training on Energy efficiency.

Type of training to support MRV system MRV process involves with data collection, storage, transmission, verification and reporting to authority responsible for transmitting to the database. In order to achieve flawless process, employees need to be educated on policy, procedures and precautionary measures related to data.

According to the survey, 44% of the respondents have received training about the MRV or Data collection system among them 20% are with academic training, about 19% with only on-board training and 5% received both kind of trainings.

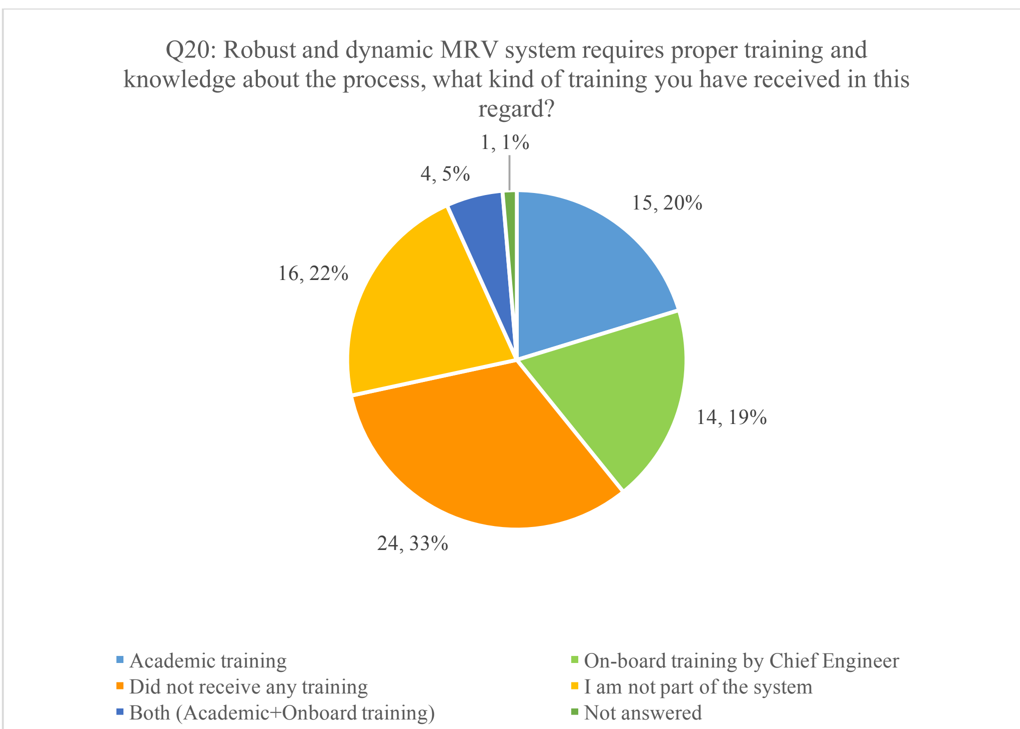


Figure 21: Training for Robust MRV System

About 33% of the respondents did not receive any training on MRV and 22% of respondents stated that they are not part of the system or process of MRV/Data collection System. According to the figures, lack of training could become an issue or barrier for effective implementation of MRV where data quality is concerned.

Crew's burden in MRV process Resolution MEPC.213(63) as well as many other regulations of IMO urges company not to increase administrative burden for ship crew. However, in reality, situation is quite contrary.

As much as 50% of the respondents believe that introducing MRV will increase administrative burden to the ship's crew, 41% suggest that it will not cause any administrative burden and 3% did not comment on the issue.

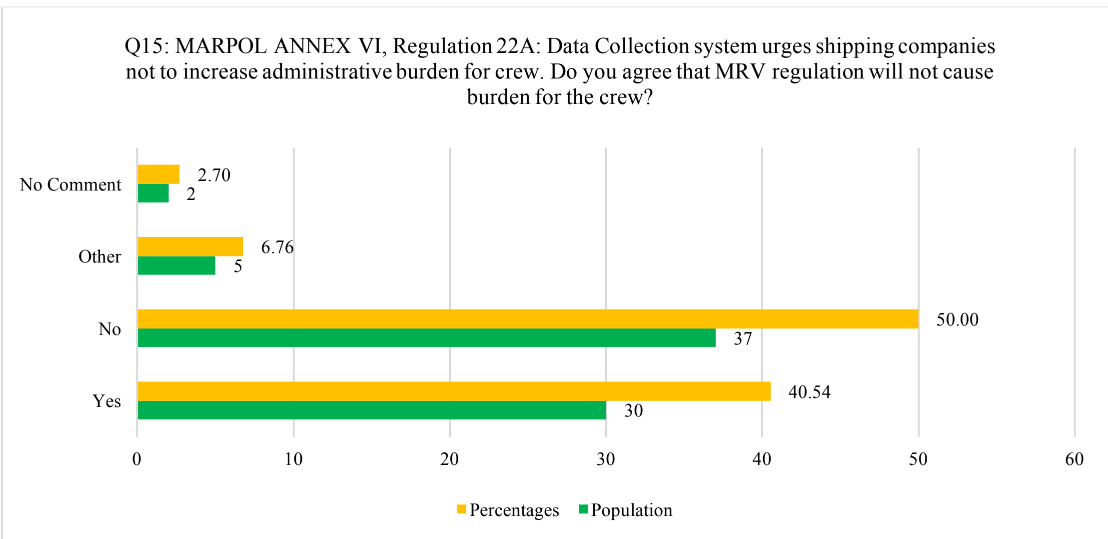


Figure 22: Removing administrative burden from crew

However, 7% given some valuable comments which says it shall cause burden for the crew as the pressure will be upon them if the company and ship owners does not act accordingly to provide the vessels with necessary support in terms of installations of necessary equipment, training and awareness, update of shipboard manuals inclusive of such changes etc. One stated that it wouldn't be considered as a burden if incentives are provided for the crew. Some believes that if MRV documentation is simplified enough, it will not cause any burden and any new regulation always needs attention at the implementation phase. Thus, majority of the population of the study believe that it will increase burden to the ships' crew. Adopting of proper procedure, training, technological support and incentives could reduce burden from seafarer.

5.2.5 Group E: Ensuring Data Quality

(What are the barriers and constraints on ensuring data quality?)

Data errors Maintaining data accuracy is the most important factor in the MRV process. There are many places where data error can occur. Identifying and eliminating data error are of major concerns for implementation of MRV.

Table 11: Survey Outcome Question 22

Factors for Data Inaccuracy	Population	Percentage
Error with the measuring device	7	9.46
Human error while collection and interpretation	37	50.00
Lack of correct procedure	20	27.03
Other	2	2.70
All of above	8	10.81

In accordance with the survey, 50% of the population believes that most important cause for data inaccuracy is the human error while data collection and 27% of the population thinks that only lack of correct procedure is responsible for data inaccuracy.

Only 9% of the population believes that error with the measuring device mostly causes the data inaccuracy while collection. Again, 8% of the population advocates for all of the above reasons are responsible for data inaccuracy. Moreover, 27% of lacking of procedure and 50% of human error, combining 77% are directly related to human factor of the data collection regime, which can be eliminated with introduction of automation. Therefore, potential measures must be researched to eliminate the error of data linked to human.

Issues with manual data collection Daily fuel consumptions on various machinery on board ships are transmitted to Head Office in electronic forms. Manual reading and entry of data into the system takes lots of effort and prone to error or misreporting. It is crucial to take into account and necessary steps to take for elimination of data error.

As observed in the survey that more than 74% of the respondents agree that the error of manual log-taking which sent to head office with noon report could be eliminated with the introduction of automated monitoring system.

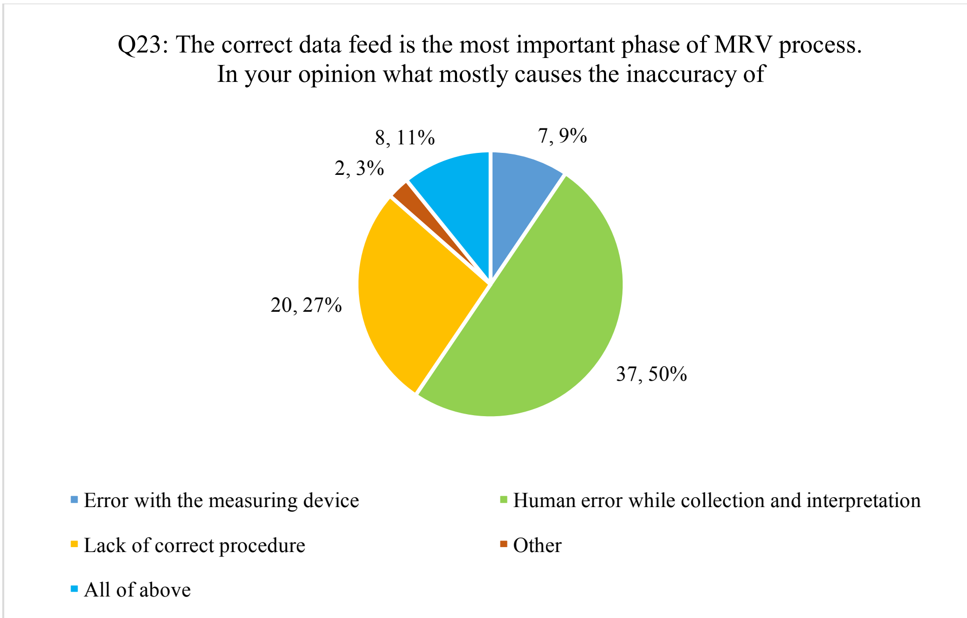


Figure 23: Issues with manual data collection

About 19% disagree with the statement including 8% of the respondents strongly disagree idea that integration of automation will eliminate data error. One suggested that what if the automated system fails? It might be better of both manual and automated system is essential, this is also to double check the validity of collected data. However, above graph clearly shows that the majority of the population advocates for the enhancement of automation for MRV process.

Maintaining data accuracy Addressing uncertainty, maintaining reliability and reducing noise are some objectives while dealing with data. Robustness of the MRV system depends on the system integrity and eliminating all existing gaps from the system. Misreporting is a noteworthy concern and could affect data base in a large scale.

In this survey, about 69% of population believes that the main cause for misreporting or wrong entry is human error or lack of knowledge about the data entry.

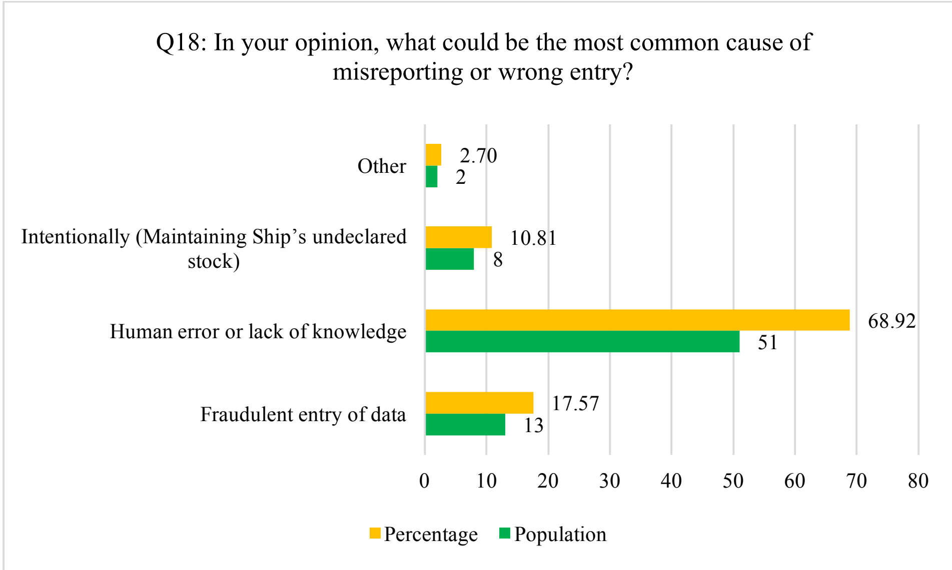


Figure 24: Cause for Misreporting

However, a significant proportion involves, about 29%, with maintaining intentional misreporting such as 11% intentionally maintaining ship's undeclared stock and 18% fraudulent entry of data, which are also related to the human related matter and eliminated with correct measures.

Existence of modern data management tool Applying CMMS allows to carry out sequential maintenance, record and transmission various ships operational data efficiently. Ships fuel consumption data recorded as it occurs in every event and transmitted accordingly. These systems could aid MRV system for proper implementation.

According to the survey, 54% of the participants have endorsed that their organizations are subscribing CMMS of different kinds, 28% as Not known and more than 9% not subscribing to any CMMS.

CMMS allows smooth data transition to the head office to vessel and any interested party in the loop of data collection process. If company wishes to integrate automated data collection system or a common platform for multiple user can be better achieved by the CMMS.

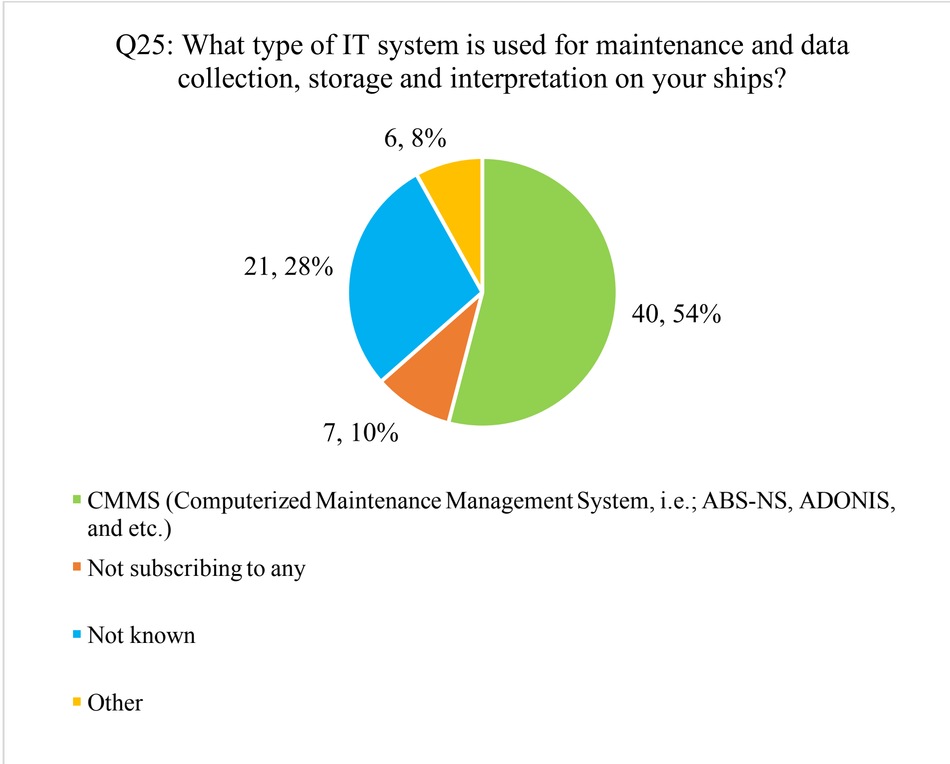


Figure 25: Type of IT system Use

Issues with data collection process According to Regulation (EU) 2015/757 and IMO. Appendix IX, Res. MEPC.278(70) Company shall define the procedure for data collection method and identify methods of detecting surrogate data and eliminating data gap. Moreover, data reporting format should be provided by the IMO and EU. Therefore, it is necessary to identify gaps prior the MRV method commences.

According to the survey, as much 70% of the participants stated that their organization have identified the potential problem with the data collection and transformation and necessary steps have been taken to improve the data quality.

It shows the commitment towards improvement of data quality of the involved companies where the participants are working. One suggested that once new regulation will be put in place then problems related to data quality will surface. Over 16% of the participants stated that no assessment has been carried out yet. For better compliance, a thorough assessment is required to be carried out and any shortcomings need to be attended.

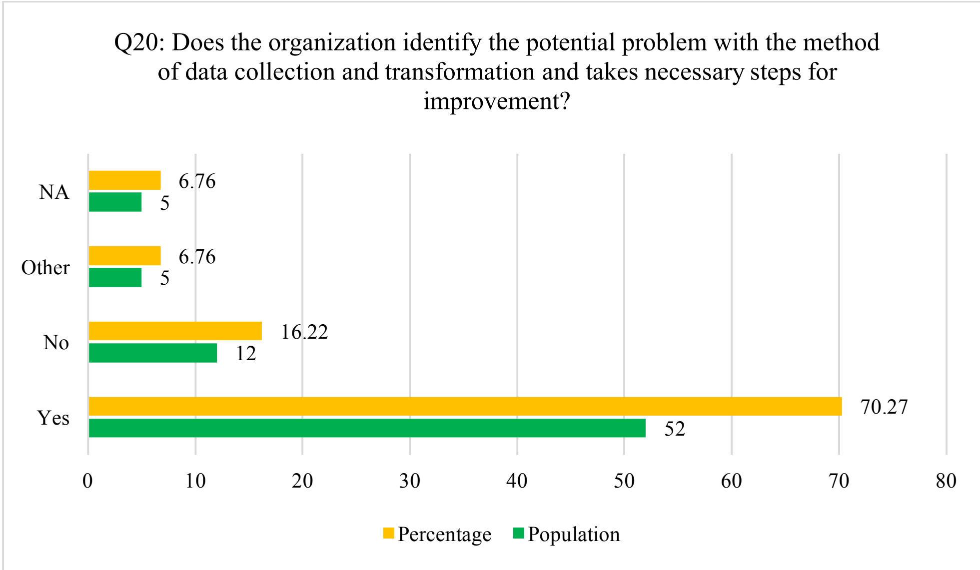


Figure 26: Problem associated with data collection

5.3 Summary

The focuses of the questions are based on the vital elements needed in the MRV system. There are many resources and systems available which can assist implementing the MRV process. However, many gaps can be found from the policy, human, technological and data quality perspectives and the study provided here could bridge the gaps. The respondents emphasized vessel's technological improvement for the data quality management, elimination of data errors with manual collection and entry, in many ways in this survey. Some of the important issues, such as operational, management, compliance, training, and data errors are needed to be answered for effective implementation of the MRV process. The maritime industry's potentials, barriers, limitations, and shortcomings regarding the energy management and the MRV process have been revealed by the survey towards better compliance.

Chapter VI

Employing TOPSIS Method- Ranking of FC Monitoring Methods

6.1 Overview

The TOPSIS model was created for selecting the best fuel consumption monitoring method. The data inputs were chosen from the available literature and analyzing present status of the selected attributes in the maritime industry. Success of such model depends on design accuracy with substantial data set. A realistic model based on the accurate data can provide better solution in the decision-making process. A MADM approach is known to provide most suitable solution based on many attributes. In this research, four attributes, namely, Data error, Cost of technology for each method, Operational and maintenance cost and Rating point obtained from the online survey, have been selected for the fuel consumption monitoring methods upon comprehending the influence of these attributes on each method:

a) Method-A: Bunker Delivery Note (BDN) and periodic stock taking in fuel tanks,
b) Method-B: Regular stocktaking of bunker tanks,
c) Method-C: Reading from flowmeters, and
d) Method-D: Direct measurement from the exhaust gas outlet.

There are multiple factors need to be studied before the selection of a monitoring method for fuel consumption. In this chapter, as alternatives, all methods for monitoring of fuel consumption are analyzed and ranked on the basis of the attributes. The estimation process of crisp numbers for the attributes for the input of the TOPSIS model are presented in detail. The TOPSIS model can help policy maker to select best method for fuel consumption monitoring which can be prioritized and exercised to eliminate noise and data anomaly.

6.2 Estimation of Data Error with FC Monitoring Methods

A calculation of fuel consumption based on various method could have error obtaining correct fuel consumption. Finding data errors from the documents is not a straight process. Therefore, for this research, the estimation of data error has relied on available documents and experts' opinion. According to Section 4.2, Chapter 4 of this research, BDN and periodic stocking are estimated to have about 1.69% of data errors, which consist of error in bunker quantity measurement (1%), impurities in fuel oil according to BDN and ISO8217 (0.65%). Errors with periodic bunker tank monitoring (estimated 1%) also have been included in this data error of 1.69%.

Similarly, Method-B: bunker tank monitoring is estimated to have 2.69% of data error. Manual checking often creates a chance to have more data errors as it depends on various factors such as, sea state, human factors, error in the instruments used for the bunker tank monitoring. The below table shows data used for employing the TOPSIS model for ranking of fuel oil consumption monitoring methods as required for the MRV system.

In the case of Method-C (Flowmeter) and Method-D (Exhaust Gas Flow Measurement), as per the IMO calibration standards for fuel oil consumption in the NOx Technical code, MARPOL Annex VI, data accuracy should be 2% and 2.5% of the engine maximum value respectively. Therefore, it can be estimated and normal to take into consideration that above two methods may cause data error of 1% and 1.25% respectively. The estimation of error has been taken as realistic and practicable as possible based on the expert's opinion.

Table 12: Potential Data Error for FC Monitoring Method

Methods of FC Monitoring	Source of Error	Percentage of Error (%)	Total Estimated Error (%)
Method-A: BDN and Periodic Stock taking in fuel tanks	BDN Quantity mismatch	1	
	Water and other impurities	0.65	
	Loss of oil during treatment	0.04	1.69
Method-B: Regular stock taking of Bunker Tanks	Error with checking or instruments or procedure	2	
	Water and other impurities	0.65	
	Loss of oil during treatment	0.04	2.69
Method-C: Reading from the flowmeter	IMO, MARPOL A-VI, Nox technical code (±2%)	1	1
Method-D: Direct Measurement from Exhaust Gas Stack	IMO, MARPOL A-VI, Nox Technical Code (±2.5%)	1.25	1.25

6.3 Estimation of Cost of technology for FC Monitoring Methods

A number of equipment of various types and standards are used for fuel consumption monitoring onboard vessels. The price of an equipment varies depending on manufacturer, locations, supplier and standard. Therefore, the estimation of Capital Expenses (CAPEX) has been conducted based on experts' opinions and market price review from different sources, such as KRAL for tank gauging devices and flowmeters, as direct prices for each method are not available in the literature.

Table 13: CAPEX of FC Monitoring Methods[9]

Methods of FC Monitoring	**Equipment or means used**	**Cost (CAPEX)$^{\beta}$**	**Estimated Average Cost (CAPEX)**
Method-A: BDN and Periodic Stock taking in fuel tanks	BDN	0	
	Manual sounding measurement (Oil Dip Sounding)	50-200	7000$^{\alpha}$
	Automatic Tank Gauges	4000-10,000	
Method-B: Regular stock taking of Bunker Tanks	Manual tanks sounding measurement	50-200	
	Automatic Tank Gauges	4000-10,000	7000
Method-C: Reading from the flowmeter	Analog Conventional Flowmeter	200-2000	
	Digital Flowmeter with data remote sensing capability	500-10,000	5250
Method-D: Direct Measurement from Exhaust Gas Stack	Analog Conventional Flowmeter	1000-5000	
	Digital Flowmeter with data remote sensing capability	5000-15000	10,000

$^{\beta}$ Values are based on experts' opinion, equipment manufacturer feedback and market study which are presented in US Dollars.
$^{\alpha}$ Calculation of Estimated CAPEX is the median value of (4000-10000) which is 7000, Similar methods are applied to other Estimated Capex values in the Table.

The price for each category is also vary, as such, assigning to a crisp number is challenging. In this case, the median of highest number range has been considered as CAPEX for an input to the TOPSIS Model.

6.4 Estimation of Operational and Maintenance (O&M) Cost for FC Monitoring Methods

[9] Range of CAPEX for fuel consumption monitoring methods are obtained from flowmeter manufacturer-KRAL and expert's opinion.

As like CAPEX, finding Operational and Maintenance (O&M) costs from the available literature is challenging. Therefore, looking at the nature of technology employed for each method, an estimation of operational and maintenance costs has been made. As BDN and periodic bunker tank monitoring has minimum technological involvement, it has been assigned with the least O&M cost for assigning of crisp numbers as inputs to the TOPSIS Model. In case of Method-B: Bunker tank monitoring, which normally require the installation of tank measuring devices, also depends on the choice of ship-owners who consider available prices and types in the market. Again, equipment used for Method-C and Method-D for fuel consumption measurements need to undergo regular maintenance regime, therefore, incur operational and maintenance costs. These estimations are based on experts' opinions, degree of complexity of a system, application and maintenance on board ship.

Table 14: O&M Costs for FC Monitoring Methods

Methods of FC Monitoring	Type of Cost	Estimated O&M Cost (Year)	Total Estimated O&M Cost (Year)$^{\propto}$
Method-A: BDN and Periodic Stock taking in fuel tanks	Operational	0	1000
	Maintenance	1000	
Method-B: Regular stock taking of Bunker Tanks	Operational	3000	6000
	Maintenance	3000	
Method-C: Reading from the flowmeter	Operational	2000	7,000
	Maintenance	5000	
Method-D: Direct Measurement from Exhaust Gas Stack	Operational	5000	12,000
	Maintenance	7000	

$^{\propto}$ Total of O & M Cost values are obtained from the expert's opinion and all are presented in U.S. Dollars.

6.5 Rating point based on respondents' preferences of the survey questionnaire

Fuel consumption monitoring methods are the most important factors for data collection and have significant influence on entire MRV regime. The opinion from the various maritime professionals on FC Monitoring methods gives credible insight of the system and helps to identify as regarded as reliable method. In Chapter 5, Section 5.2.3, rating point from the outcome of the survey questionnaire has been deduced which are presented as below.

Table 15: Rating point from the survey for FC Monitoring Methods

	Method-A	Method-B	Method-C	Method-D
Rating from the survey	158	157	146	151

The Method-A, Method-B, Method-C and Method-D have been rated by respondents with the numbers of 158, 157, 146 and 151 respectively. These data from the survey questionnaire (Question 13) has to be fed into the TOPSIS model as an attribute.

6.6 Data input to the TOPSIS model

The values for the four selected attributes from different sources inserted into the TOPSIS model (See Table 16). In this case, all four attributes which are negative factors for the Methods and holistically to MRV process. Thus, they are considered as COST attributes.

In case of "Rating from the survey" attribute, considering the preference of respondents and structure of the question, the lowest the number is most preferable. Therefore, it is justifiable to consider the "Rating from the survey" as the COST attribute.

Table 16 Data Inputs for TOPSIS Model

Attributes	Alternatives				Attributed Weight
	Method-A	Method-B	Method-C	Method-D	
Data Error	1.69	2.69	1	1.25	0.4
Cost for technology	7000	7000	5250	10000	0.2
Operational and maintenance Cost	1000	6000	7000	12000	0.1
Rating of survey	158	157	146	151	0.3

All crisp numbers from the above analysis are fed into the TOPSIS model which could provide a decision as regard to the selection of best method for fuel consumption.

6.7 Weighing the Attributes

According to Olcer and Odabasi (2005), fuzzy numbers in this phase are translated into crisp numbers to make the arithmetic process easier. Weight for each attribute has been assigned from expert's opinions according to the below table.

Table 17 Assigning weights to the attributes

Attributes	Expert's Opinion
Data Error	0.4
Cost for Technology	0.2
Operational and Maintenance cost	0.1
Rating from Survey Questionnaire	0.3
Total	1.0

The value (X) for each attribute should be $0 \leq X \geq 1$, however, the aggregated value of the attributes should be 1.

6.8 Ranking phase of fuel Consumption monitoring methods

The ranking of the methods, Method-A: Bunker Delivery Note (BDN) and Periodic stock taking in fuel tanks, Method-B: Regular Stocktaking of the bunker tanks, Method-C: Reading from Flowmeters, and Method-D: Direct measurement from exhaust gas outlet, are the representation of consideration of each attribute on its designated weight.

Table 18: TOPSIS ranking

	Method- A	Method- B	Method- C	Method- D
RANK	1	2	3	4

By employing data to the TOPSIS Model, presented in Appendix 4, the ranking of methods for fuel consumption monitoring are obtained as in the Table 18. In terms of cost effectiveness, data errors and the preference of industry, Method-A has been ranked as most the desired method, followed by Method-B, Method-C and Method-D.

6.9 Summary

The CAPEX and OPEX are the most important deciding factors for the shipowner to choose the FC monitoring methods. Method-A is most desired fuel consumption monitoring method to a ship owner as CAPEX and OPEX are less for implementing MRV process and the method is also less complicated in terms of equipment use. In the case of Method-D, a large amount of expenses is required and it is not as common onboard a ship as other methods. In fact, only a few ships are equipped with such devices in the world merchant fleet.

The majority of ship owners also consider Method-A as the most preferred for the FC Monitoring. It has been verified by the industry experts as well as representatives of authorized verifiers in several occasions during this research. A certain degree of estimation for determining the value of the attributes have been taken into use due to approximation, however, the data errors due to estimation have been minimized through the opinion of targeted experienced respondents.

Chapter VII

Effective Implementation of MRV- Barriers and How to Deal with Them

7.1 Overview

An exploratory study from multiple perspectives, such as from the policy, technological, human element and data management, have been conducted to identify the barriers to the MRV process on implementation. The identification of barriers is a complex process which requires a wide range of knowledge from regulatory requirements to vessel's data collection system as well as vessel operators' active participation. A holistic approach to identify barriers to the MRV process from the vessel's perspective has been adopted for this research. In this chapter, barriers are explored through analyzing vessel's data collection systems, and assessment from multiple perspectives. The barriers have been identified and solutions have been suggested in due course. With regards to implementation of the MRV process, overcoming strategies to mitigate the impact of barriers and possible solutions are discussed.

7.2 Associated barriers to the MRV process from the vessel's perspective

To carry out an assessment on prevailing methods for data monitoring and reporting, vessel's Engine Room Log book, Chief Engineer's Log Abstract have been evaluated. The SEEMP, EEDI and EEOI have been reviewed as well. The IMO-DCS and EU-MRV system are similar and requirements of monitoring, reporting and verification are quite in line with each other besides minor differences. Both approaches were reviewed focusing on certain criteria, such as, literature, regulatory requirements and system elements of the MRV for identification of barriers. The outcome of questionnaire survey, among maritime experts in different countries and their specialist opinions, facilitated better identification of barriers from the industry perspective.

Table 19: Identified Barriers

Assessment	Barriers
Policy	Lack of effective energy management policy adoption in an organizational level Lack of coordination with other Energy efficiency regime Repetition of data on various level (CE Log book, CELA, MRV data) Lack of commitment Lack of procedure for data collection Non-availability of Energy Management Team onboard vessels Lack of integrity in reporting mechanism
Technological	Lack of new technology uptake (Auto-logging, quality technology for data collection) Adherence to analog system of DCS (maintaining paper form) Using sub-standard equipment with error
Human related	Lack of knowledge or training Lack of Motivation to adopt new technology for DCS Misreporting/ Wrong or fraudulent data feed Lack of training on Energy efficiency and DCS Excessive human involvement (Human-Machine interaction) in data collection process Overburdened vessel's staff with administrative duties
Other barriers	Lack of resource allocated for Energy efficiency enhancement IMO's Non-binding targets for Energy efficiency improvement measures causing no regulatory pressure (EEOI)

In this research, the process of identification of the barriers potentially facilitated possible removal of the barriers and should help adoption of any other energy efficiency measure in the future as well. Moreover, the elimination of above barriers described in Table 6 will not only ensure better implementation of the DCS, but also can be useful for the shipping industry's drive to go carbon neutral.

7.3 Addressing Prevailing Barriers

The effective implementation of the MRV process is not possible without the knowledge of any possible barriers to prevent the process. By addressing all the barriers effectively, a robust data management system to carry out seamless data monitoring, storage and reporting regime coordinated along with other energy management drives can be achieved. Integration of all existing and upcoming energy management policies and measures to develop a unified system which could ensure all the objectives towards flawless MRV are met and even act upon reducing administrative burden of ship personnel.

Maritime energy-related technology uptake in the maritime industry is not as dynamic as other industries due to several reasons which includes the lack of incentives, non-binding environmental regulations in national and international level, and the availability of cheap bunker fuel (See Section 3.3.2, Figure. 6). However, recent developments in mandatory regulations such as EEDI and upcoming MRV are expected to promote technological uptake for better compliance. Phasing out of substandard equipment and uptake of new technologies will ensure efficient operation, monitoring and significant emission reduction from the maritime transport.

Motivated, skilled and well-trained vessel's crew and energy management team are assets to the MRV regime. Ship's staff must be well-trained on data management, such as maintaining data accuracy, robustness, transparency and integrity of data. Ship's staff must not be overloaded with administrative burdens for data collection duties, therefore, training on the management of the administrative loads, management of handling huge amount of data. A certain degree of automated data logging and transmission must be incorporated in the vessels systems. Improvement in the ship's technology in this case will ensure enhanced compliance and elimination of data manipulation and fraudulent entry by ship crew.

Lack of resources in the areas, such as, technological, human and policy are considered as barriers to the implementation of the MRV system on board ships. Many companies are reluctant to adopt new measures related to energy efficiency onboard ships due to multiple reasons. Sometimes, ship owners do not find it attractive to avail such resources to be integrated in vessels due to a lack of incentives, therefore, the industry experience resistance to change and upgrade towards green technology. Consequently, adopting stricter regulations developed by the member states in the IMO or in regional setting can ensure positive changes towards green technology and achieve CO2 emission reduction in the maritime industry.

7.4 Elimination of barriers through Data Quality Management (DQM)

Data quality management (DQM) is one of the important tools for the effective implementation of the MRV regime in the maritime industry. In terms of integrity of data, reliability, reduction of noise, Data Quality Management (DQM) is necessary for a robust MRV system. DQM requires eliminating the data holes and minimizing leakage. Data holes are existed in different sensors' intervals, manual human interference, sensor breakdowns, and etc. (Konovessis, Thong, 2017). Importance of intake of automation is a matter of huge significance to ensure data quality which has been identified by this research.

Within the DQM, maintaining data accuracy is of principal factors for MRV regime which is affected by many attributes, for example, equipment used for data collection, availability of data, method of analysis. During the verification process, verifier must ensure that data accuracy is maintained and in compliance with relevant standards. Data accuracy check could be performed by "Plausibility Check" for fuel consumption data and vessel's other activity data cross checked with AIS data (VARIFABIA, 2017). Upon ensuring maintaining data quality, minimizing data gap, and uncertainty of data ship's tracking data could be used to perform plausibility check for confirming the fuel consumption data by the verifier. Vessels' inputs of MRV associated data, such as, Engine room log book, Chief engineer's log abstract, and other dynamic data inputs have to be checked by the verifier during the certification for verification and compliance. A certain degree of automated inputs of data with precision equipment and minimal error need to be complied with for maintaining utmost data accuracy and reliability. The review of various ships' modes of data inputs and the experts' opinion in Chapter 3, 4 and 5 of this dissertation highlights on data accuracy and ways to maintain accuracy while considering data gaps. Data gaps for MRV system have to be assessed on three criteria which are data collection process, procedure for data transformation, details of company's operational documentation and regulatory requirement for MRV process. Measurement uncertainties can be introduced in many ways which are, a) uncertainty introduced by sensors inaccuracy, b) through sampling process, frequency, and c) use of imperfect information. As described in ISO 19030-1:2016, in order to make the DQM effective, data uncertainty needs to be done through experts' assessment on available resources and applicability in specific case by case basis.

Errors exist in every system and equipment onboard ship in a certain extent which causes noise in data collection system. Addressing uncertainty, identification of sensitive parameters influencing fuel consumption data, enhancement of reliability and reduction of noise are critically important for MRV process. Selection of best method for FC monitoring (in Chapter VI), from the data and economic perspectives, could facilitate removal of hindrances from the monitoring process.

7.5 Role of stakeholders on removal of barriers for the MRV regime

For the both cases, IMO-DCS and EU-MRV system, active participations of all parties are extremely essential and all stakeholders must have uninterrupted linkage between them for a seamless data flow. In the case of the EU, the below Figure 27 illustrates data flow and the involvement of parties in the MRV process. In this case, when regulations are set by the European Commission (EC), all member states, authorized verifier, shipping companies and all stakeholders in the link required to perform their parts simultaneously and deliver an effective MRV system.

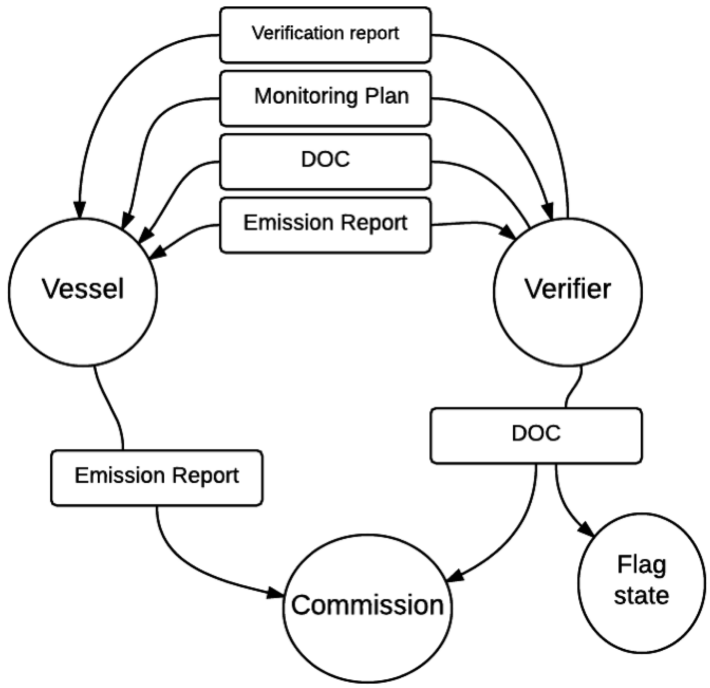


Figure 27: Data flow between parties in EU-MRV process

The EU member states are actively ensuring total compliance and a CO_2 emission database established with reliable data gathered from vessels. Similar approaches have been under by the IMO member states for establishment of the global fuel consumption database.

7.5.1 The role of IMO Member States

Administration plays a vital role in the MRV process, therefore, it's role on removing barriers is also significant. According to the IMO, administration shall ensure the data is transferred to IMO fuel consumption database in a prescribed format developed by the IMO within one month of issuance of the *Statement of Compliance* to the company (Res. MEPC. 278(70)). The company shall report to Administration/RO (Recognized Organization) the aggregated data not more than 3 months of end of the reporting period (1 January to 31 December). Moreover, the Administration should also ensure that the Data Collection Plan is approved prior 1January 2018 (Res. MEPC.282(70)). Similarly, for the EU, member states' obligation to the MRV by implementing as below (Regulation (EU) 2015/757).

- Conducting Accreditation of the verifier,
- Inspect ships under its jurisdiction and ensure compliance,
- Ensure valid documents are carried on board,
- Impose penalties in case of any non-compliance,
- Report to Commission if any penalties or expulsion from its port imposed any of visiting ship, and
- Technical cooperation and exchange of information with the other country.

Therefore, providing guidelines, incentives for better compliant vessels, awarding and promoting energy efficiency enhancement drives throughout the jurisdiction of an administration can help implementing the MRV regime.

7.5.2 Recognized Organization/ Accredited Verifier

The role of a Recognized Organization (RO) certified and accredited by Administration, works under the procedures and guidelines developed by Administration for the requirement of verification and reporting and additional inspections require by the Administration (Resolution A739(18), MARPOL Annex VI), can ensure barriers related to technological, human and administration are properly dealt with.

Verifier gets accredited by National Accreditation Body of Member state	
VERIFIER (Competent and accredited)	Approval of Monitoring Plan by verifier
	Comparison of Reported Data/Charectaristics with Ship tracking data(AIS) provided by Commission
	Verify Emission Report
	Issue Verification Report
	Issue Document of Compliance

Figure 28: Scope of a Verifier

As verifier ensures all the requirements of the MRV process under the guidelines of the administration are met. Ensuring strict compliance to the regulations, providing expertise and advices to the vessels, sharing knowledge with the company towards developing efficient data management system a verifier can ensure objectives of the MRV process are achieved.

7.5.3 The Company's role on eliminating barriers of MRV system

Implementation of the MRV process depends largely on policy and actions taken by a company. A shipping company acts as a bridge between the parties for transmitting information and regulating the whole process of the data collection system. A company plays significant role in the data collection process which includes ensuring the ships with up-to-date monitoring plan included in the SEEMP and verified, methodology for data collection systems are defined, collected data are reported to the RO (Verifier) and Statement of Compliance (SOC) issued and carried on board.

Effective eradication of the barriers by steps, such as, adoption of greener policy, embracing new technology for data collection and transmission process, removing knowledge gaps and proper management of resources in this regard could facilitate effective implementation of MRV and also promote energy efficiency across fleet.

7.5.4 Vessel's role on eliminating barriers of MRV system

Many of the barriers for implementation of MRV associated with vessel's fuel consumption monitoring system, crew and vessel's data management system. As a vessel is placed at the center of a MRV system, the accuracy, credibility, robustness and efficiency of a MRV process depend on expertise, knowledge and motivation of the vessel crew.

Vessel should carry SOC at all time	
VESSEL (MRV Compliant)	Assessment for compliance (Internal)
	Gap Analysis
	Development of Monitoring Plan (MP)
	Verification and getting approval of MP
	Data Collection, Storage, Transmission
	Obtain SOC/DOC

Figure 29: Vessel's role on MRV System, Source: Adopted from Res. MEPC 282(70)

A few positive steps towards elimination of barriers as represented in Table 19, such as, proper resource allocation and adoption policy towards eradicating policy related barriers, providing training to the ship staff on data management, reducing administrative pressure from the crew, development of a comprehensive monitoring plan, ensuring strict compliance, and support from the head office could allow vessel to implement MRV process efficiently.

7.6 Summary

The present trend and operational practices of the maritime industry need to be improved for the barriers and constraints to be eliminated, consequently, the goals for the effective MRV process can be achieved. However, Poulsen and Johnson (2016) conclude that the recent business practices in the maritime industry do not permit to search for correct MRV practices. The identified barriers and the stakeholder's role towards progress from this stage will aid advancement of the MRV process. Early implementation of data collection process for MRV with proper equipment is subjected to the facilitation of timely compliance. Various sources of data can be streamlined, and system integrity needs can be tested prior to the implementation of the EU-MRV system starting on 1 January, 2018 and for the IMO member states from 1 January 2019.

Chapter VIII

Conclusion and Recommendations

8.1 Conclusion

This research has been designed to identify barriers to the implementation of the MRV process in the shipping industry. In doing so, firstly it analyzes the existing energy efficiency measures, documentations, and regulatory requirements for upcoming MRV regime. Secondly, it examines barriers from the multiple perspectives through an online survey and analyzing potential data errors. Finally, it identifies specific barriers and best method of fuel consumption monitoring on board ships and finds ways how the barriers for the MRV system could be eliminated through identification and mitigation.

Technological development has made the IMO's energy efficiency drive to come into reality. From 2009 and onwards, the IMO has introduced several energy efficiency measures, i.e. SEEMP, EEDI, EEOI, and etc. In July 2017, the IMO subcommittee meeting, MEPC 71, heralded that about 2,500 of new ships are EEDI compliant till date, which is a significant improvement in Energy efficiency regime. However, the SEEMP and EEOI onboard ships are still considered as less effective and decorative. This study scrutinizes comparative pictures of SEEMP, EEDI, EEOI, and MRV in Chapter 2, additionally, several questions of survey questionnaire also reveal the gap between these energy efficiency measures onboard ships. The effective implementation of the MRV could be ensured by two factors, such as bridging the gaps between energy efficiency measures and ensuring their strict regulatory compliance.

For any regulatory regime to be successful, it is necessary to understand its standpoint and prevailing barriers. Firstly, identifying barriers to the MRV process on policy, technological, human perspectives and effectively eliminating the barriers to facilitate successful implementation are the objectives of this study. In Section 7.3, Chapter 7, this study identifies how the barriers could be effectively eliminated or minimized. Moreover, the better understanding of the regulatory requirements, existing energy efficiency drives, and their effectiveness, reviewing vessels' various technical issues and employing scientific methods for decision-making purposes have been carried out in this research. These will potentially expedite effective implementation of MRV System and play a significant role in the reduction of shipping emissions. Secondly, besides the elimination of the barriers, ways in which data accuracy is maintained is vital and also a part of the objectives of this research. This study identifies also the potential data errors and ways to mitigate them in Chapter IV, V, and VII which confirms the achievement of the objectives of this research to a certain extent. Again, the IMO-DCS and EU-MRV systems for establishing a fuel consumption database require a high level of accuracy in data collection for these systems to be reliable for future adoption of MBMs.

The cumulative effect of MRV along with other regulatory procedures will be far greater in future when emission reduction measures and MBM's will be applied throughout the maritime industry and beyond. It is estimated that the effective implementation of EU-MRV system will result in 2% reduction of shipping emission in the EU region (EU Commission, 2015). Moreover, the global implementation of the data collection system will encourage energy efficiency enhancement measures are adopted and the vessels will be more technologically advanced. The MRV process in the shipping industry requires various stakeholders to act on a common platform seamlessly and develop a global fuel consumption database for future policy making towards sustainable shipping. The guidelines and regulations set by the IMO and EU Commission on the MRV need to be complied and adopted in due course without leaving any shipping companies behind. It is challenging because of diverse corporate objectives of the shipping companies whose vessels are sailing in various parts of the world and some are eventually come and trade in EU. Therefore, a harmonized system of the MRV is essential for effective data collection, reporting, and verification process.

8.2 Recommendations

Non-implementation of the data collection, monitoring and verification systems and other energy efficiency measures are caused by the absence of robust and reliable data which are missing in the maritime industry. The IMO-DCS and EU-MRV system would be able to bridge the gap and support the shipping industry to become more sustainable. Adoption of the below steps could ensure effective implementation of the MRV systems in the maritime industry-

a) Digitalization of the log books for recording ships operational static and dynamic data,
b) Improvement of automation and monitoring technology (i.e. fuel metering, remote sensing devices)
c) Adoption of policy inclined to enhancement of energy efficiency throughout the company,
d) Adoption of stricter policy (e.g. suitable MBM's) and compliance at the international level by the IMO member states,
e) Elimination of repetition of same entry of data into various places (e.g. Log book/Log abstract/Emission report/Head Office Transfer),
f) Making data publicly available with particulars of vessel and the company operating to ensure level playing field,
g) Introducing "MRV AUDIT SCHEME" – to ensure strict compliance by removing monitoring hindrances and confirming robustness of data,
h) Providing quality training to staff involved in data collection and transformation process, and

Above all, ***all-inclusive participation*** and ***commitment of leaders*** of the maritime industry and policy makers could make the MRV system implemented effectively.

8.2.1 Limitations and Suggestions

This research discusses significantly the documentations and fuel consumption measuring equipment on board ship, nevertheless, there were limitations of resources to avail ship's visits and interview ship's staff in person. The allocation of time for the research, non-availability of data, reliance on secondary data and no physical visits to the vessels were some of the implications of this research. The MRV system is in the conceiving stage, therefore, the literature on the shipping MRV process is yet to flourish. A few estimations have been made for determining the price for fuel consumption monitoring devices, tank gauging systems and estimating data errors which can create some uncertainty in the TOPSIS result.

The research has identified barriers concerning the maritime MRV. The future research can address the aspect of commercial barriers for the MRV system, which was not focused in this study. A detail research on the DQM involving ways enhancing data quality, method of monitoring, factors affecting data quality should be conducted in the future. Moreover, study on the potential technology use for the MRV system can also deepen the knowledge in this area in the future.

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Appendix 1: Survey Questionnaire

Master's Dissertation Questionnaire

ENSURING EFFECTIVE IMPLEMENTATION OF MONITORING, REPORTING AND VERIFICATION (MRV) SYSTEM IN SHIPPING; A STEP TOWARDS MAKING ENERGY-EFFICIENCY HAPPEN

* Required

1. **Email address ***

____

Consent

Please check below boxes to give your consent:

2. **"By completing this questionnaire, I consent to my personal data being used for this study and other research. I understand that all personal data relating to volunteers is held and processed in the strictest confidence. I understand that my participation is entirely voluntary and that I can withdraw at any time." ***

   Check all that apply.

   ☐ Yes

Group A: General

3. **Which one of the below groups you belong to in the shipping industry? ***

   Mark only one oval.

   ◯ Ship Managers
   ◯ Ship's Engineers
   ◯ Navigating officers
   ◯ Other: ________________________________

4. **Which one of the following best describes your gender? ***

   Check all that apply.

   ☐ Male
   ☐ Female
   ☐ Others

5. **Which one of the below age groups you belong to? ***

   Mark only one oval.

   ◯ 18-24
   ◯ 25-34
   ◯ 35-45
   ◯ 45+

6. **What is the level of your academic qualification?** *

Mark only one oval.

- ◯ Masters and above
- ◯ Bachelor
- ◯ Diploma on maritime affairs
- ◯ Other: ____________

Group B: Policy Perspective

How are the shipping companies getting ready, setting up policy and strategy, prior kicking off IMO's Data Collection System (MARPOL ANNEX-VI, Reg-22A) and EU MRV (Reg. 2015/757) System?

7. **1. Does your company operate according to the requirements and guidelines of the International Standards, such as-?**

Check all that apply.

- ☐ ISO 14001: 2015 (Environmental)
- ☐ ISO 50001: 2011 (Energy Management)
- ☐ ISO 9001: 2015 (Quality) and
- ☐ Other: ____________

8. **Is Energy Efficiency included in any of the followings in your company?**

Check all that apply.

- ☐ The company's corporate goals and objectives
- ☐ Quality Management System
- ☐ Not included at all.
- ☐ Other: ____________

9. **Recently, in many companies, a dedicated Energy Management Team is employed to monitor energy efficiency of the company. Does such energy department exist in your company?**

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Other: ____________

10. **As IMO's Fuel Consumption Monitoring, Reporting and Verification (MRV) System starting from 1 Jan 2019, similarly every ship entering/leaving EU, voyage and annual aggregated data for CO2 emission are to be reported to the Administration from 1 Jan 2018. What is the status of your company regards to implement MRV system for any of your vessel?**

Check all that apply.

- ☐ Ship specific Monitoring Plan Approved by Accredited Verifier
- ☐ Consideration given for policy adoption
- ☐ Not engaged in EU bound voyages
- ☐ Not aware of such rules.

11. **In your opinion, what would be the impact of MRV on the existing Ship Energy Efficiency Management Plan (SEEMP) for energy saving in your domain?**
Mark only one oval.

- ◯ Will affect positively in large extent
- ◯ Minor positive impact
- ◯ No effect at all
- ◯ Negative effect on SEEMP

Group C:Technological Standpoint

What are the existing technology gap for proper implementation of MRV process in shipping?

12. **What is your view on the installation of "Real-time online fuel consumption monitoring device" to collect data from remote location as a solution for MRV process?**
Mark only one oval.

- ◯ It is the best solution.
- ◯ It is as good as other solutions.
- ◯ Not sure
- ◯ It is not a good solution.
- ◯ Other: ____________________

13. **According to IMO and EU, there are four engine Fuel consumption measurement methods, listed as- Method-A: BDN and periodic stock takes of fuel tanks, Method-B: Bunker tanks monitoring, Method-C: Flowmeter for applicable combustion process, and Method-D: Direct CO2 emission measurement method from exhaust uptakes (For EU MRV)Please enter number in below boxes for ranking based on your preference (Most preferred=1, Least preferred=4)**
Mark only one oval per row.

	1	2	3	4
Method A	◯	◯	◯	◯
Method B	◯	◯	◯	◯
Method C	◯	◯	◯	◯
Method D	◯	◯	◯	◯

14. **What are the means of getting ship's daily dynamic data readings on your vessel?**
Mark only one oval.

- ◯ Auto-logging with sensors (Continuous monitoring)
- ◯ Manual logging (at every 24 hour)
- ◯ Other: ____________________

15. **In your view, what is the most important factor for improving data quality?**
Mark only one oval.

- ◯ Improved collection procedures and management
- ◯ Auditing regime
- ◯ Improved automation (installing sensors)
- ◯ Other: ____________________

16. **Is your ship assessed for compatibility for MRV (Retrofitting option) technology gap to meet IMO and EU requirement?**

Mark only one oval.

- Assessed by External MRV service provider
- Assessed by Internal experts
- Status not assessed
- Other: ______

Group D: Human Element

What is the status of expertise, knowledge and awareness of ship's crew on correct data feed, monitoring, reporting and verification requirements?

17. **Are you aware of the development of regulatory requirement by IMO and European Union regarding MRV process?**

Mark only one oval.

- Yes
- No
- Other: ______

18. **SEEMP requires the company to develop plan with specific roles and responsibilities for personnel to improve energy efficiency on board, do you have any specific role of such kind in your organization?**

Mark only one oval.

- Yes, designated for specific duties
- No
- Other: ______

19. **What kind of training you or your crew receives to increase awareness, familiarity and knowledge on SEEMP/EEOI/Ship's Energy Efficiency?**

Check all that apply.

- [ ] In-house training sessions as per SEEMP
- [ ] Customized training by External experts or institution
- [ ] Not participated any training about EnE
- [ ] Other: ______

20. **Robust and dynamic MRV system requires proper training and knowledge about the process, what kind of training you have received in this regard?**

Check all that apply.

- [ ] Academic training
- [ ] On-board training by Chief Engineer
- [ ] Did not receive any training
- [ ] I am not part of the system

21. **MARPOL ANNEX VI, Regulation 22A: Data Collection system urges shipping companies not to increase administrative burden for crew. Do you agree that MRV regulation will not cause burden for the crew?**
Mark only one oval.

- ( ) Yes
- ( ) No
- ( ) Other: ____________

Group E: Ensuring data quality

What are the barriers and constraints on ensuring data quality?

22. **The correct data feed is the most important phase of MRV process. In your opinion what mostly causes the inaccuracy of data?**
Check all that apply.

- [ ] Error with the measuring device
- [ ] Human error while collection and interpretation
- [ ] Lack of correct procedure
- [ ] Other: ____________

23. **Manual log taking, entry of data and reporting to HQ with Noon Report, this whole process of ships emission data collection consists of significant amount of error and could be eliminated by employing automated monitoring system. To what extent do you agree with the above opinion?**
Mark only one oval.

- ( ) Strongly disagree
- ( ) Agree
- ( ) Disagree
- ( ) Neutral
- ( ) Other: ____________

24. **In your opinion, what could be the most common cause of misreporting or wrong entry?**
Mark only one oval.

- ( ) Fraudulent entry of data
- ( ) Human error or lack of knowledge
- ( ) Intentionally (Maintaining Ship's undeclared stock)
- ( ) Other: ____________

25. **What type of IT system is used for maintenance and data collection, storage and interpretation on your ships?**

Mark only one oval.

- ( ) CMMS (Computerized Maintenance Management System, i.e.; ABS-NS, ADONIS, and etc.)
- ( ) Not subscribing to any
- ( ) Not known
- ( ) Other: ____________________

26. **Does the organization identify the potential problem with the method of data collection and transformation and takes necessary steps for improvement?**

Mark only one oval.

- ( ) Yes
- ( ) No
- ( ) Other: ____________________

Powered by Google Forms

Appendix 2: Review of the Engine Room Log Book

Engine Room Log Book:

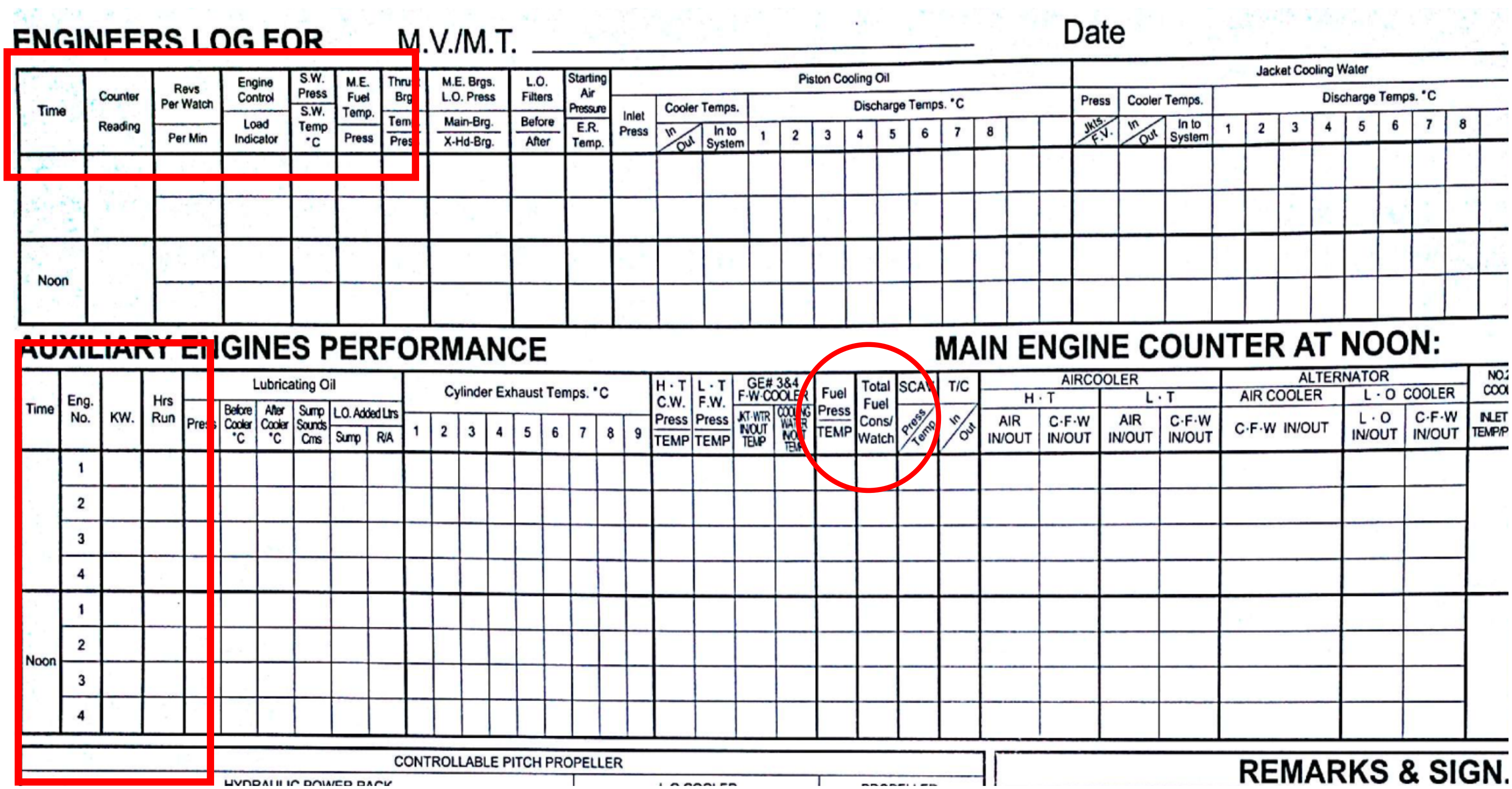


Figure 30: Engineers Log Book, Page 1

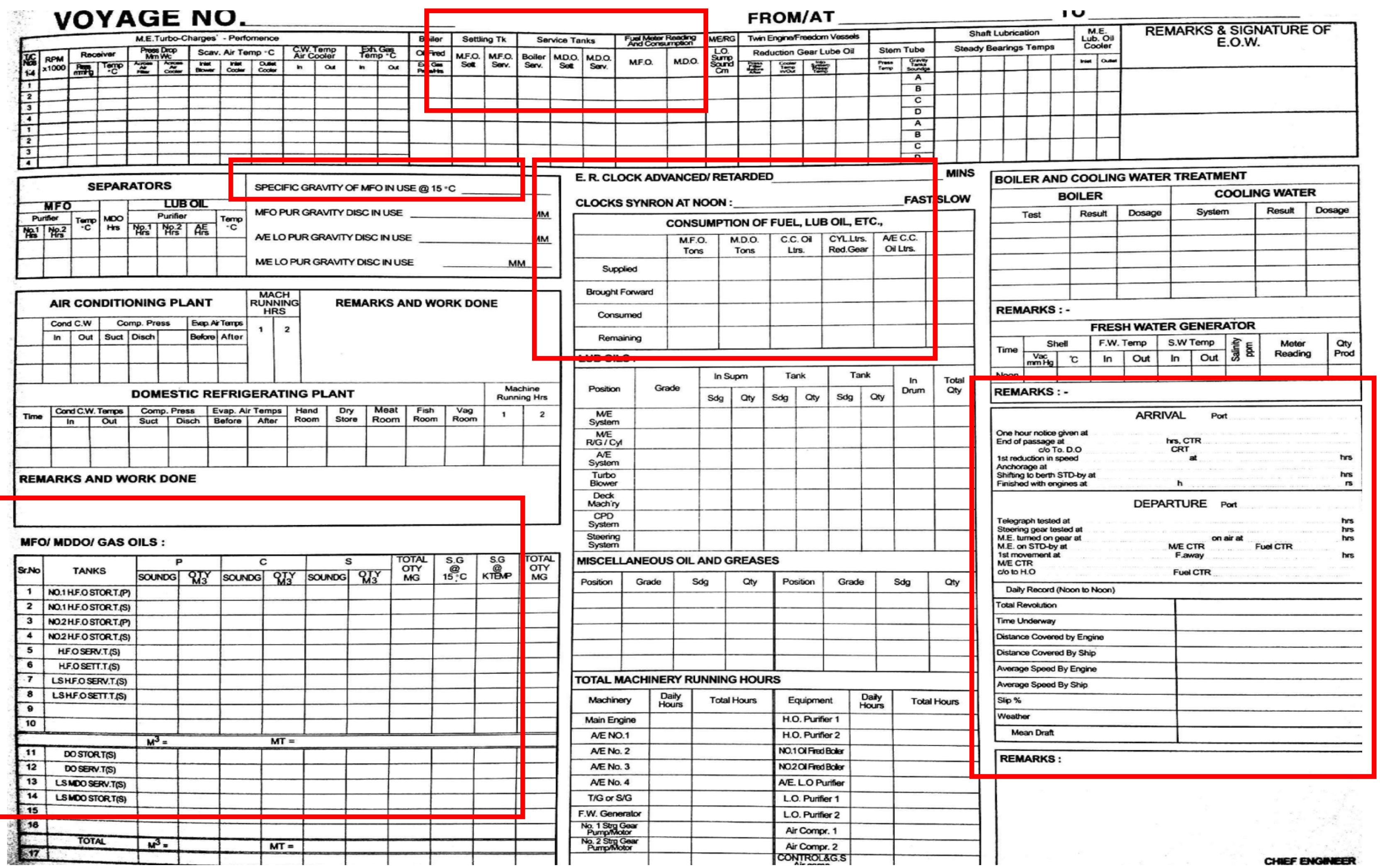


Figure 31: Engineer's Log Book, Page 2A

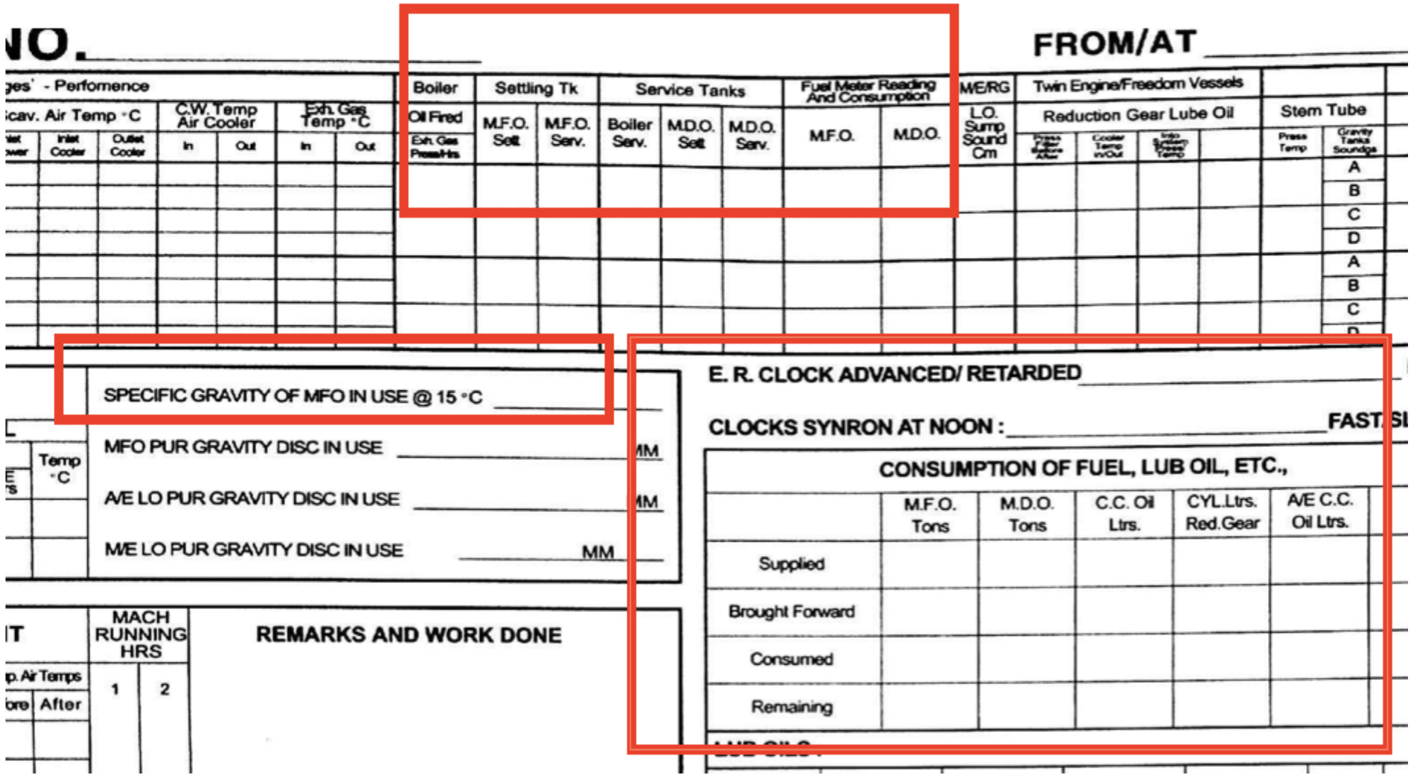


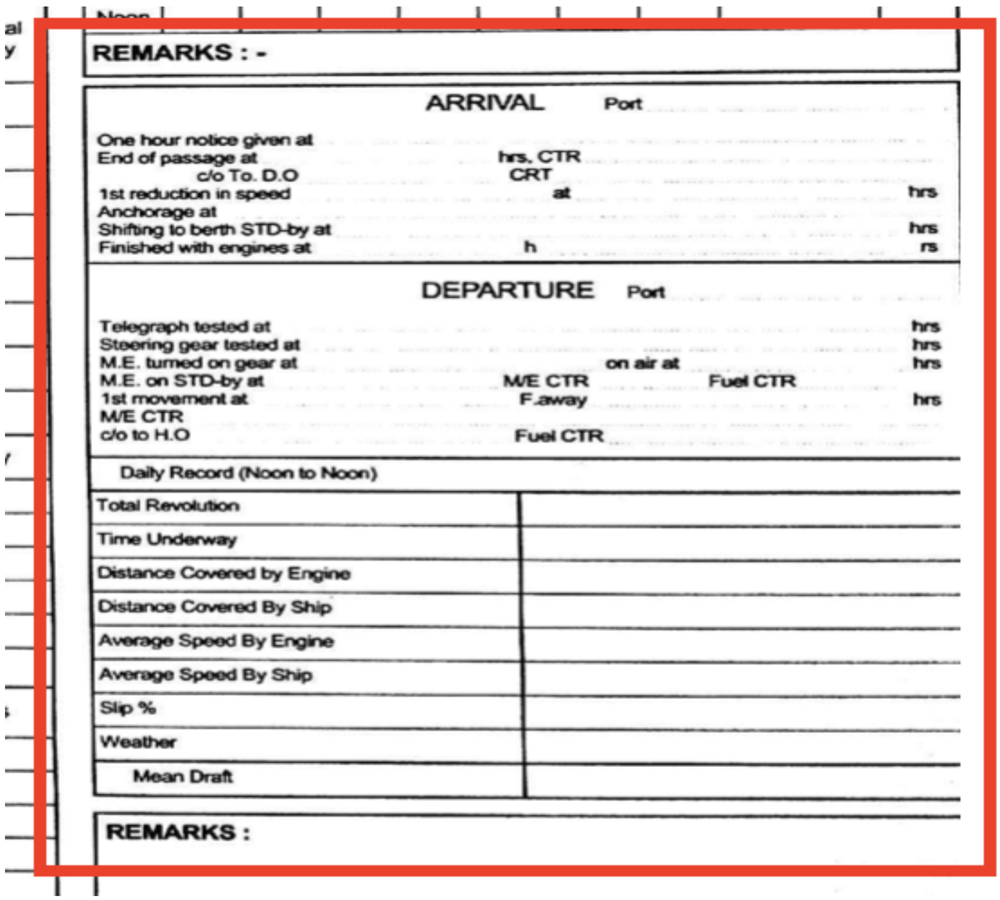
Figure 32: Engineer's Log Book, Page 2B

REMARKS AND WORK DONE

MFO/ MDDO/ GAS OILS :

Sr.No	TANKS	P		C		S		TOTAL QTY MG	S.G @ 15°C	S.G @ K TEMP	TOTAL QTY MG
		SOUNDG	QTY M3	SOUNDG	QTY M3	SOUNDG	QTY M3				
1	NO.1 H.F.O STOR.T.(P)										
2	NO.1 H.F.O STOR.T.(S)										
3	NO.2 H.F.O STOR.T.(P)										
4	NO.2 H.F.O STOR.T.(S)										
5	H.F.O SERV.T.(S)										
6	H.F.O SETT.T.(S)										
7	L.S H.F.O SERV.T.(S)										
8	L.S H.F.O SETT.T.(S)										
9											
10											
		M^3 =			MT =						
11	DO STOR.T(S)										
12	DO SERV.T(S)										
13	L.S MDO SERV.T(S)										
14	L.S MDO STOR.T(S)										
15											
16											

Figure 33: Engineer's Log Book, Page 2C


REMARKS : -

ARRIVAL Port

One hour notice given at
End of passage at hrs, CTR
c/o To. D.O CRT
1st reduction in speed at hrs
Anchorage at
Shifting to berth STD-by at hrs
Finished with engines at h rs

DEPARTURE Port

Telegraph tested at hrs
Steering gear tested at hrs
M.E. turned on gear at on air at hrs
M.E. on STD-by at M/E CTR Fuel CTR
1st movement at F.away hrs
M/E CTR
c/o to H.O Fuel CTR

Daily Record (Noon to Noon)	
Total Revolution	
Time Underway	
Distance Covered by Engine	
Distance Covered By Ship	
Average Speed By Engine	
Average Speed By Ship	
Slip %	
Weather	
Mean Draft	

REMARKS :

Figure 34: Part of Engineer's Log Book Page 2D

Engine Room Log Book Extract:

Data entry in engineer's log book is carried out by vessel crew daily in very watch. The readings are collected manually and entered into the log book. In Figure 33 to 37, readings in Engineer's Log Book Used for Fuel Consumption calculations are as presented below.

A) Time,
B) Main Engine Revolution Counter Reading,
C) Main Engine FO Temperature and Pressure,
D) Auxiliary Engine Running Hours, Load, Fuel pressure, temperature and Total Fuel Consumption,

E) Total Fuel Consumption per watch,

F) Fuel Meter reading and consumption (MFO and MDO),

G) Specific Gravity of MFO in use at 15^0C,

H) Consumption of Fuel Oil (Noon to Noon)- MFO and MDO for Quantity Supplied, Brought Forward, Consumed and Remaining on board,

I) Tank Content- MFO, MDO and MGO- Storage Tank, Settling Tank, Service Tank content, Sounding, Quantity M^3, Total Quantity and Specific gravity at 15^0C,

J) Port arrival and Departure Information, such as, time for End of Passage, One Hour Notice, time at anchorage, time of Main engine running including fuel counter and fuel change over time., and

K) Daily Record (Noon to Noon) for total revolution, time underway, distance covered by ship, distance covered by engine, Average engine speed and ship's speed, slip (%), weather condition and mean draft.

On the basis of gauge readings, engineer on watch or chief engineer calculate the fuel consumption which is transmitted to the head office as part of daily reporting schedule, normally at every noon. Above information is required for the determination of fuel consumption and to feed into the MRV process.

Appendix 3: Review of a Chief Engineer's Log Abstract

Chief Engineer's Log Abstract:

K226

Vessel

Year : 2017

From 31-Dec-2016 'NOON' To 31-Dec-2017 'NOON'

Voyage information, Date & Time, Event and Mode

Row	Voy Num	Event Start Date & Time	Event End Date & Time	Previous Event	Current Event	Mode	From Port	To Port	Clock Advance (-1) /Retard (+1)	Hours	Vsl Status
20	1708V	22-Apr-17 23:18	23-Apr-17 07:42	FAOP	EOP	SEA	GOLA	LAKE CHARLES		8.4	LADEN
21	1708V	23-Apr-17 07:42	23-Apr-17 09:06	EOP	F.W.E.	MANU	GOLA	LAKE CHARLES		1.4	LADEN
22	1708V	23-Apr-17 09:06	23-Apr-17 12:00	F.W.E.	NOON	ANCH	GOLA	LAKE CHARLES		2.9	LADEN
23	1708V	23-Apr-17 12:00	24-Apr-17 12:00	NOON	NOON	ANCH	GOLA	LAKE CHARLES		24	LADEN
24	1708V	24-Apr-17 12:00	25-Apr-17 12:00	NOON	NOON	ANCH	GOLA	LAKE CHARLES		24	LADEN
25	1708V	25-Apr-17 12:00		NOON			GOLA	LAKE CHARLES			
26	1708V										
27	1708V										
28	1708V										
29	1708V										
30	1708V										
31	1708V										
32	1708V										
33											

Figure 35: Contents of Chief Engineer's Log Abstract-1

/hen vessel at "PORT"/ "STS"/"SBM", - Status
hould be either "LOADING"/ "DISCHARGE"

0.1559488 0.0025991

Weather informations & Sea condition						M/E Revs, RPM, Distances travelled and Slips								
Vessel Heading/ Course	Wind Force (BF scale)	Relative Wind Direction	Sea State	Weather	Wave Height (M)	M/E Revs	Eng RPM	Eng Dist	Eng Spd	Distance over ground GPS	Ship Speed (by GPS) (Knots)	Apparent Slip (%)	Distance Through Water (N.Mil)	STW (Knots)
							-	-	-	27.0	7.71			
							-	-	-					
							-	-	-					
							-	-	-	10.0	0.59			
							-	-	-	6.0	0.53			
						45,400	90.1	118.0	14.0	99.0	11.79	16.1%		
							-	-	-	6.7	4.79			
							-	-	-					
							-	-	-					
							-	-	-					

Figure 36:Contents of Chief Engineer's Log Abstract-2

Displacement figure must be entered as per stability records (file B09)corrected for daily consumptions

B/L figure must be entered. In case of multiple parcels - enter total MT of cargo onboard

As per Lab test report

As per Lab

	Draft, Displacement & Cargo				HSFO BF. ROB						806.6	
True Slip (%)	Fwd Draft (M)	Aft Draft (M)	Displacement (MT)	Cargo Carried (MT) B/L figure	Net LCV of HFO (in use	HSFO cons ME (MT)	HSFO cons AE (MT)	HSFO cons BLR (MT)	HSFO Cons Total (MT)	HSFO Received (MT)	HSFO ROB (MT)	Net LCV of LSMGO (in use
	5.6	8.6	59,717.0						0.0		638.0	42.76
	5.6	8.6	59,717.0						0.0		638.0	42.76
	5.6	8.6	59,717.0						0.0		638.0	42.76
	5.6	8.6	59,717.0						0.0		638.0	42.76
	5.6	8.6	59,717.0						0.0		638.0	42.76
	11.2	11.2	97,982.0						0.0		638.0	42.76
100.0%	11.2	11.2	97,982.0						0.0		638.0	42.76
	11.2	11.2	97,982.0						0.0		638.0	42.76
	11.2	11.2	97,982.0						0.0		638.0	42.76
	11.2	11.2	97,982.0						0.0		638.0	42.76
	11.2	11.2	97,982.0						0.0		638.0	42.76

Figure 37:Contents of Chief Engineer's Log Abstract-3

b Test report

Applicable to Eagle Miri and Eagle Madrid

As per Lab test report

Applicable to Eagle Miri and Eagle Madrid

Fuel Oil Consumption and ROB

LSMGO (Sulphur content<0.1% m/m) BF. ROB						637	MGO (Sulphur content> 0.1% m/m) BF. ROB							0
LSMGO cons ME (MT)	LSMGO cons AE (MT)	LSMGO cons BLR (MT)	LSMGO cons IG Generator (MT)	LSMGO consTotal (MT)	LSMGO Received (MT)	LSMGO ROB (MT)	Net LCV of MGO (in us	MGO cons ME (MT)	MGO cons AE (MT)	MGO cons BLR (MT)	MGO cons IG Generator (MT)	MGO cons Total (MT)	MGO Received (MT)	MGO R (MT
	2.2	2		4.2		233.9						0.0		
3.3	0.5	0.2		4.0		229.9						0.0		
	0.1	0.1		0.2		229.7						0.0		
	0.8	0.8		1.6	300.6	528.7						0.0		
3.0	4.2	2.5		9.7		519.0						0.0		
0.9	1.7	2.7		5.3		513.7						0.0		
13.5	0.8	0.1		14.4		499.3						0.0		
0.5	0.2	0.2		0.9		498.4						0.0		
	0.3	0.3		0.6		497.8						0.0		
	2.4	2.5		4.9		492.9						0.0		
	2.2	2.3		4.5		488.4						0.0		

Figure 38:Contents of Chief Engineer's Log Abstract-4

and			CYL Oil consumption and ROB			Fresh Water consumption and ROB						Miscellan			
		0	BF.ROB →		59279	BF. ROB →		89	BF. ROB →		114				
	MGO Received (MT)	MGO ROB (MT)	ME CYL OIL cons (LTRS	ME CYL Oil Received (LTRS	ME CYL OIL ROB (LTRS)	FW cons (MT)	FW PROD/ Received (MT)	FW ROB (MT)	Feed W. cons (MT)	Feed W. PROD/ Receive (MT)	Feed W. ROB (MT)	M/E Load	M/E Scav. Air temp (°C)	E/R Temp (°C)	Sea Wat Temp (°C)
0		0.0	30		74670.0	2.0		178.0			120.0			33.0	2
0		0.0	0		74670.0	-		178.0			120.0			34.0	2
0		0.0	-		74670.0	2.0		176.0	1.0		119.0			35.0	2
0		0.0	27.0		74643.0	3.0		173.0	1.0		118.0			35.0	2
0		0.0	8.0		74635.0	2.0		171.0			118.0			33.0	2
0		0.0	80.0		74555.0	2.0	9.0	178.0			118.0			35.0	2
0		0.0	6.0		74549.0	-		178.0			118.0			30.0	2
0		0.0			74549.0	1.0		177.0			118.0			28.0	2
0		0.0			74549.0	5.0		172.0			118.0			28.0	2
0		0.0			74549.0	5.0		167.0			118.0			30.0	2

Figure 39:Contents of Chief Engineer's Log Abstract-5

eous					
er	M/E Avg. Shaft Power (if Torqu meter	SFOC (gm/kw	Mile/Ton (ME on	Mandatory C/E Remarks	Additional Remarks
3.0					
4.0			8.2		Deparure from galvaston to GOLA lightering area
4.0					Anchored Gola for bunker . LSMGO 300.59mt bunkered
4.0					Departure GOLA and proceeding for STS
4.0			3.3		STS Operation with VLCC . Loading commenced @0400hrs
4.0			6.7		Loading completed at 1800hrs and departure to lake charles
4.0			7.3	None	Arrival to Lake charles
4.0			13.4		Anchored at lake charles
4.0					ANCHORED
4.0					ANCHORED
4.0					ANCHORED

Figure 40:Contents of Chief Engineer's Log Abstract-6

Appendix-4: TOPSIS Model

Result of the TOPSIS Model:

Below figure represents TOPSIS Analysis of the Method A, Method B, Method C, and Method D against each attribute.

Cost=1, Benefit=0

Method-A: BDN+ Periodic checking of Bunker tanks
Method-B: Measuring of Bunker tanks
Method-C: Flowmeters
Metho-D: Measuring Exhaust Gas flow

ATTRIBUTES	ALTERNATIVES				Attributed Weight	Cost/Benefit	Nomalised matrix	SQRT	Normalised			
	Method-A	Method-B	Method-C	Method-D					Method-A	Method-B	Method-C	Method-D
Data Error	1.69	2.69	1	1.25	0.4	1		3.55734452	0.47507347	0.75618203	0.28110856	0.3513857
Cost for technology	7000	7000	5250	10000	0.2	1		15018.7383	0.46608442	0.46608442	0.34956332	0.66583489
Operational and maintenance Cost	1000	6000	7000	12000	0.1	1		15165.7509	0.06593805	0.39562828	0.46156633	0.79125657
Rating of survey	158	157	146	151	0.3	1		306.153556	0.51608089	0.51281456	0.47688487	0.49321655
					1							

Figure 41: TOPSIS Model- Part 1

Weighted normalised				Positive ideal	Negative ideal	(vij-PI)^2					(vij-NI)^2			
Method-A	Method-B	Method-C	Method-D			Method-A	Method-B	Method-C	Method-D		Method-A	Method-B	Method-C	Method-D
1.18768367	1.89045508	0.7027714	0.87846426	0.7027714	1.89045508	0.23513991	1.41059251	0	0.03086798		0.49388765	0	1.41059251	1.02412542
2.33042212	2.33042212	1.74781659	3.32917446	1.74781659	3.32917446	0.3394292	0.3394292	0	2.50069271		0.99750623	0.99750623	2.50069271	0
0.65938047	3.95628284	4.61566331	7.91256568	0.65938047	7.91256568	0	10.8695652	15.6521739	52.6086957		52.6086957	15.6521739	10.8695652	0
1.72026964	1.70938185	1.58961625	1.64405516	1.58961625	1.72026964	0.01707031	0.0143438	0	0.0029636		0	0.00011854	0.01707031	0.00580865
					Seperation from PI	0.76918101	3.55442411	3.95628284	7.4258481	Seperation from NI	7.35527631	4.08041649	3.84680656	1.01485667
					CI	0.90532524	0.53444685	0.49298507	0.12023364					
					RANK	1	2	3	4					

Figure 42: TOPSIS Model Part-2