

**A STUDY ON GHG EMISSION IN SHIPPING SECTOR AND THE ROLE OF
EU & IMO REGULATIONS TOWARDS GHG REDUCTION**

*Project report submitted for partial fulfilment of the requirement for the award of
degree of*

Master of Business Administration

Port and shipping management

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DECLARATION

The Project work titled “**A STUDY ON GHG EMISSION IN SHIPPING SECTOR AND THE ROLE OF EU & IMO REGULATIONS TOWARDS GHG REDUCTION**” has been carried out under the direction of **Dr. Emil Mathew**, Assistant Professor, School of Maritime Management, Indian Maritime University-Chennai Campus in partial fulfilment of the requirements for the award of degree of **Master of Business Administration in Port and Shipping Management** to be submitted to the School of Maritime Management, Indian Maritime University, Chennai Campus. This is the original work done by me and that’s not a part of any other work.

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CERTIFICATE

School of Maritime Management

Indian Maritime University, Chennai.

This is to certify that the project report entitled “**A STUDY ON GHG EMISSION IN SHIPPING SECTOR AND THE ROLE OF EU & IMO REGULATIONS TOWARDS GHG REDUCTION**”, submitted to the School of Maritime Management, Indian Maritime University, Chennai Campus., in partial fulfilment for the award of the degree of Master of Business Administration in Port & Shipping Management is a record of work carried out entirely by **Mr.Ram Subramani R**, Reg. No.2003304024.

Dr.Emil Matthew

Project Guide

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CHAPTER - I

INTRODUCTION

1.1 GHG EMISSION IN MARITIME SECTOR

Reducing greenhouse gas (GHG) emission is the world hot topic to limit the global warming and it's the important step to avoid the disastrous impact of climate change. Many countries around the world has taken positive approach towards GHG reduction as per as Paris agreement. The primary goal is to keep climate change under 2° C beyond pre-industrial levels, hence limiting temperature rise by 1.5° C. Although shipping has been in the agenda of Paris agreement, IMO has taken numerous sustainable shipping measures and adopted its own strategy to reduce GHG emission in worldwide shipping. It is very necessary to understand the trend of various factors in shipping which is responsible for emission. To ensure sustainable planet it is very necessary to follow stainable shipping practices. Thus international body IMO has devised GHG reduction strategy to fight against global warming.

The modern maritime connectivity is enhanced with new innovative sustainable technology and energy efficient ship design. In spite of those innovative technology introduction into shipping, the GHG emission and other pollutants from this sector is significant on global scale. Shipping industry has numerous varieties of emission polluting both air and water bodies.

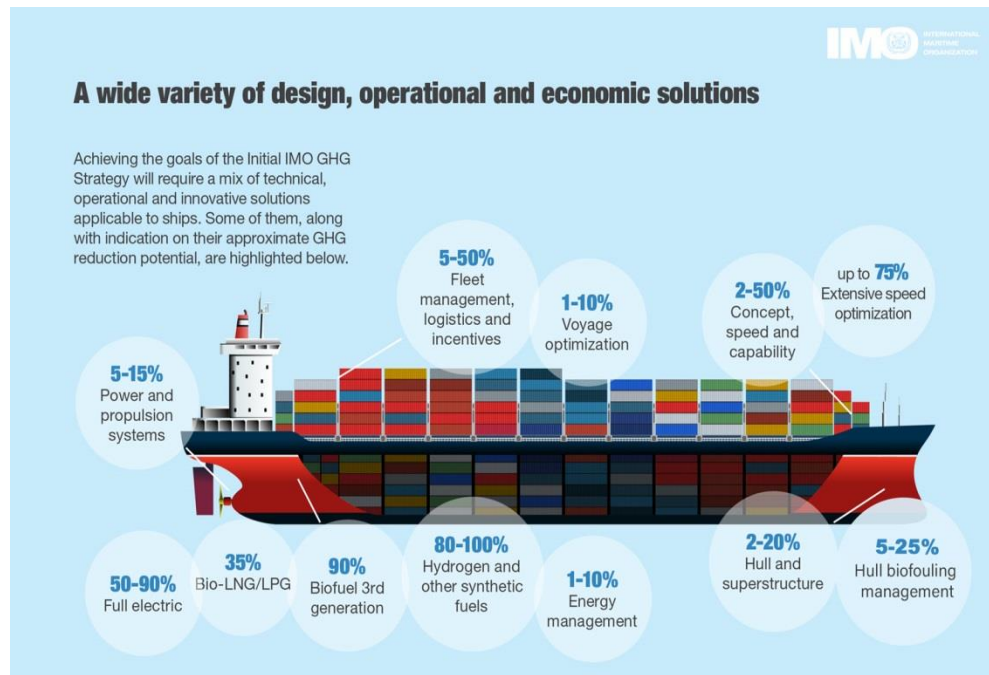
- GHG emission is one of the threatening pollution in shipping sector and CO₂ from ship is the major contributor
- Other emission from shipping are sulfur oxide (SO_x) which is responsible for acid rain and nitrogen oxide (NO_x) which pose a serious concern towards the undesirable effect to human health.
- Other emissions like Carbon monoxides, Particulate Matter (PM) pose a series threat to human health.

In past few decades the importance of sustainable shipping has grown and it has been highlighted in terms of GHG emission from ship and the ballast water, treated sewage water which is discharged directly into water body or in port reception facility.

According to the Third IMO GHG Study, the maritime industry emits around 940 m tonnes of CO₂ per year, accounting for approximately 3% of world GHG emissions. If no immediate actions to cut emissions are adopted, the IMO projects that this proportion would grow to 15% by 2050.

1.2 INITIAL IMO GHG STRATEGY

Fig 1.1- Technical and Operational measures of IMO GHG Strategy 2018



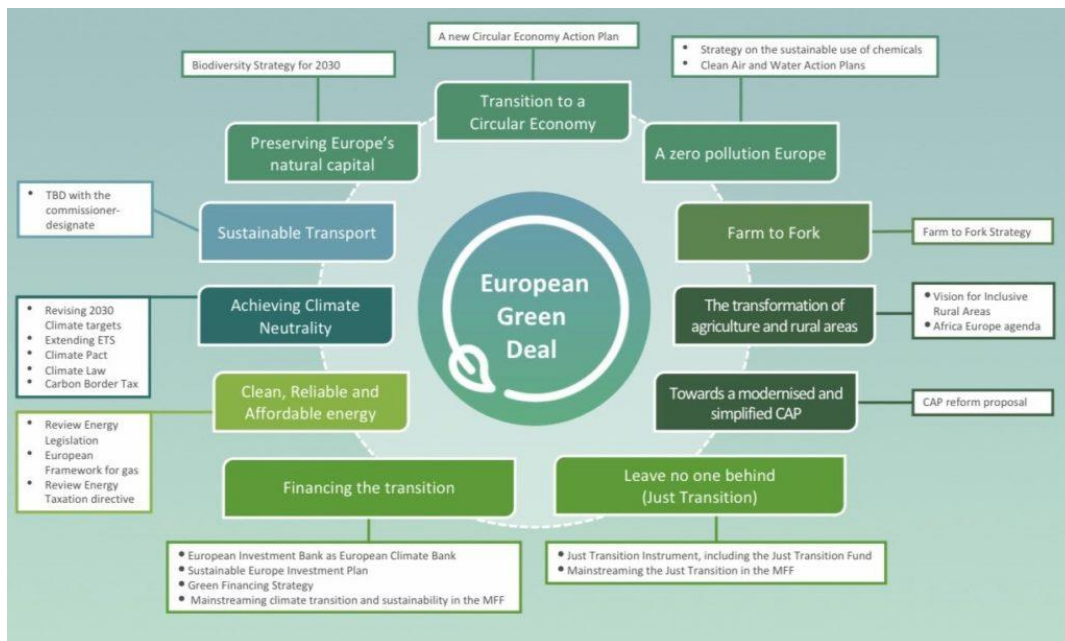
(Source-IMO)

To aid UN SDG 13, IMO is still making a difference in the worldwide battle against climate change. The strategy mentions “a CO₂ emission reduction strategy consistent with the Paris Agreement temperature targets.” This approach identifies bottlenecks and measures of assistance, such as technical assistance, and Research & Development. The plan forecasts that a new approach will be implemented in 2023. IMO is also carrying out worldwide technical assistance projects to assist states, especially emerging nations, Fuel efficiency in the maritime sector must be implemented and supported. In 2018, the IMO enacted an initial plan for reducing polluting gas from ships, laying out a vision that underlines the IMO's commitment to

decreasing, and eventually eliminating, Global carbon emissions shipping. The IMO has implemented required measures to reduce greenhouse gas emissions from shipping under the pollution control treaty (MARPOL), such as the Energy Efficiency Design Index (EEDI) for new ships and the Ship Energy Efficiency Management Plan (SEEMP). The first approach gives as a framework for Member States, articulating the vision for the future for international shipping as well as levels of ambition to decrease GHG emissions and guiding principles. It also provides potential additional actions for the short, medium, and long term, as well as timetables and state consequences.

1.3 EUROPEAN UNION PLAN

Fig 1.2- European Green Deal 2020



(Source-EUOPARC)

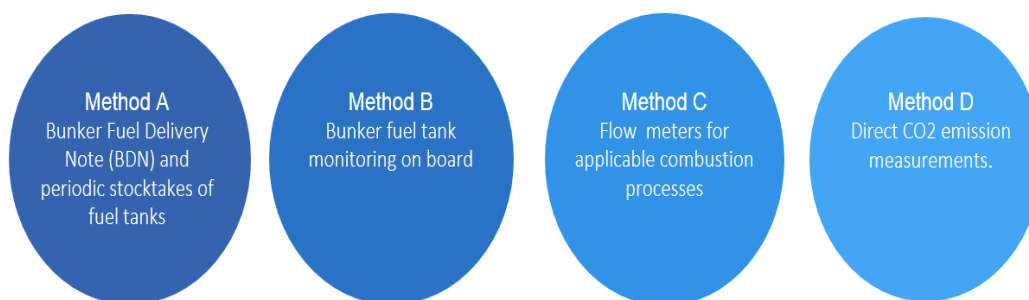
The shipping company is under the jurisdiction of the Member Nations, which guarantees compliance with the same rules as other sectors under ETS. The proposal is subject to debate and negotiation before it is adopted by the European Parliament and its member states. It has been proposed to gradually expand ETS to the maritime sector from 2023 to 2025. In this proposal, ETS will be expanded to emissions from all vessels over 5000 gross tons, regardless of flag. The

EC proposes expanding the scope of ETS to include the marine industry. Trading aims to provide flexibility to ensure reduced emissions where the costs are lowest. Individual Member Nations may establish themselves own rates as long as the minimum rates are met. EU-ETS & Absolute to the total amount of specific greenhouse gases that companies covered by the scheme can emit each year set a limit or "upper limit". The shipping company must purchase and abandon ETS emissions for every ton of reported CO₂ emissions. This proposed regulation applies to all vessels over 5000 gross tons, regardless of flag. The proposal includes revisions to existing legislation and a set of new measures. In Dec 2019 the EU commission presented the Green Deal. The European Climate Law sets the EU's commitment to climate neutrality and the tentative goal of reducing net greenhouse gas emissions by 2030 with binding legislation. Therefore, it is not yet known what the final terms of the proposed bill will be. First, the plan creates a new tax rate structure based on the energy content of fuel and electricity, as well as environmental performance.

1.4 METHODS USED FOR CALCULATING FUEL CONSUMPTION IN SHIP

Fig 1.3- Fuel consumption monitoring methodologies

Four available monitoring methodologies available



$$\text{CO}_2 \text{ Emissions} = \text{Fuel consumption} * \text{Emission factor}$$

(Source- IMO)

Calculating the emission from ship at greater accuracy is a challenge and this setup to monitor adds additional costs for the stakeholder.

Actual fuel usage for each journey must be utilized and computed using one of the techniques listed below:

Below are the different methods used for the calculation of actual fuel consumption:

1. A: Timely stock availability of fuel tanks and the Bunker delivery note (BDN)
2. B: Onboard monitoring of bunker fuel tanks
3. B: The monitoring method of Bunker fuel tanks onboard the ship
4. C: To monitor the flow of fuel into the combustion chamber
5. D: The setup to measure the emission directly.

1.5 RECENT ADVANCEMENT IN SUSTAINABLE GREEN SHIPPING

Cargo ships are becoming much more environmentally friendly than they are today. And like the first sailing vessel to date, today's global shipping companies use wind to move goods cheaper and cleaner across the ocean. Although the ship still needs an innovative engine to enter and exit port, designers believe that harnessing wind power may decrease carbon emissions by up to 90%. Despite the current limitations of, green hydrogen looks to play a vital role in lowering Carbon emissions in the maritime sector, despite the fact that it is not a large fuel source. Mass introduction of green hydrogen seems to be years away, but the potential for reducing carbon emissions from transportation is virtually endless. It's only a matter of time before green hydrogen becomes one of the most powerful fuel sources in the world, with zero greenhouse gases and a strong energy density sufficient to power the largest cargo ship. Danish shipping company Maersk recently announced testing of a new 600kWh battery in the size of a shipping container to reduce the energy demands and emissions of one of the large cargo ships. Batteries may not be able to power the entire cargo ship without advances in technology, but energy storage is important to reduce global vessel emissions, especially when combined with renewable energy. This approach (formerly known as "deceleration operation") turns off the

engine could save fuel and decrease CO₂ emissions from transportation. The most significant of them is, perhaps, to limit the amount of products that must be sent anywhere in the globe as an efficient approach to cut carbon emissions in the shipping / logistics business.

1.6 OBJECTIVES OF THE STUDY:

1. To understand the EU and IMO regulations and data collection system for GHG emission in shipping sector.
2. To analyze the growth rate of fuel consumption, CO₂ emission and Time spent at sea.(2018-2020)
3. To analyze the role of various factors influencing CO₂ emission in different shipping sector.

1.7 SCOPE OF THE STUDY:

The scope of this project is to study CO₂ emission in European Water and various international policies to reduce GHG emission.

This report compares various effective regulation of EU, IMO and its data collection methodology

This report has a statistical model which interprets various variables which affects CO₂ emission in various categories of ship sailing through European Water.

1.8 RESEARCH METHODOLOGY:

This study is not based on any primary data sources and relies entirely on secondary data sources. All these secondary data sources are collected from EU MRV database. Various statistical tools are used to analyze the CO₂ emission.

1.9 LIMITATION OF THE STUDY:

Limitations are the restrictive under conditions which the researcher has to carry on his work. Such restrictions are necessary and even unavoidable for the researcher to set boundaries by limiting the scope of findings.

The limitations of the study are as follows:

1. The study relies solely on secondary data.
2. The study is confined to CO₂ emission in European water.
3. The study focuses on the aspect of the methods adapted by the IMO, EU in GHG emission.
4. The statistical model is made through the data collected from EU-MRV database.

1.10 CHAPTER SCHEME:

INTRODUCTION: A brief introduction about the shipping GHG and CO₂ emission and different strategy adopted by IMO and EU for reducing the same.

REVIEW OF LITERATURE: The review of literature contains the body of the body that carried a brief analysis on the GHG and CO₂. Around 30 reviews of literature have been sourced in this report.

A REVIEW ON IMO Vs EU REGULATIONS: This chapter discuss about various steps taken by IMO and EU. It also discuss about difference between the data collection system adopted by IMO and EU. This will give a bird eye view in understanding about the different regulations, and its effectiveness toward the reduction of GHG emission in shipping.

ANALYSIS OF EMISSION DATASET WITH DIFFERENT STATISTICAL MODEL: Various statistical tools have been used to analyze the emission dataset obtained from EU MRV.

FINDINGS, SUGGESTION and CONCLUSION: The overall findings and the interpretation of statistical outcome about various variables of a ship affecting the total CO₂ emission.

Chapter - II

LITERATURE REVIEW

Lindstad, E., & Riialand, A. (2020) - This article discuss about the GHG emission from LNG based fuel ships across the world. It also explains about various models and parameters which is responsible for the increase in CO2 emission. It gives various effective calculation methods such as Well to Tank (WTT), Well to Wake (WTW) etc. for the investigation of fuel usage and various on-board systems to reduce the GHG emission. It gives us concrete understanding towards the usage of LNG as a fuel in place of HFO with an insight of economic implications. It calls for amendment in existing policies and calls up very stringent regulation with proper data collection systems to derive the real GHG emission in shipping.

Shi, W., Xiao, Y., Chen, Z., McLaughlin, H., & Li, K. X. (2018) – This paper has made a detailed analysis of various sustainable green shipping articles published over a period of 30 years and considered over 213 samples for the review. As per the study the major pollution in shipping is air pollution and it explains about evolution of modern green shipping practices. It also explains various technical measures, recycling methods in those practices. It stresses upon establishing green shipping best practices to take forward the fight towards climate change and to strengthen the R&D towards innovating various systems for the reduction of CO2 emission. It gives a global perspective to set up an international forum for researchers who can give effective suggestions and could co-operate in deriving the standards and laws of green shipping.

Misra, A., Panchabikesan, K et al (2017) - Ports contributes for around 3% of overall greenhouse gas (GHG) global emissions. The Chennai port in India consumes a massive quantity of power and fuel for multimodal movement of cargo and other important services. The accounting of GHG emissions at the Port of Chennai is created by calculating for the port's different facilities, as well as the residential colony and fishery harbour, which are managed by the Chennai Port. GHG emissions are quantified in accordance with the Panel On climate Change and World Port Environment Initiative recommendations. The port and hub facilities

were estimated to emit 280,558 tonnes of CO₂e/year. Several GHG reduction options are measured and described, as well as their impact.

Olmer, N., Comer, B. et al (2017) - This report gives a broad view of CO₂ emission and assessed various parameters across various ship categories. The findings of this research suggest that both CO₂ emission and fuel consumption is increasing even though there is an improvement in technical efficiency of various categories of ships. This suggests that the emission is concentrated towards some categories of ships and flag states. It says how different parameters affects the CO₂ emission in shipping and its effective of various accounting methods and the effects of black carbon emission in shipping sector. It also explains about the speed factor in shipping and various categories of ships and its implication towards pollution.

Bouman, E. A., Lindstad, E. et al (2017) – This article expands about global emission with respective shipping on various verticals. It also explains various ways to reduce emission with innovative technologies and increasing operational efficiency. It also explains 22 different measures to reduce CO₂ emission, thus moving towards IMO GHG Plan (2018). It also explains how to reduce emission in fleet worldwide scenario. Swift adoption of different regulatory policies devised by international organization can reduce CO₂ emission substantially. The growth factor of maritime transport is an important factor in the success towards the inclusion of various modern and innovative technologies in maritime sector.

CHAPTER – III

A REVIEW ON IMO Vs EU REGULATIONS

The task of decarbonizing in shipping sector is very significant but the technology is very expensive and it's complicated. Various international associations are working on the regulations to make the decarbonizing step effective. The decrease of GHG emissions from ships is critical for decarbonizing the maritime sector. This chapter reviews the regulations of IMO and EU for reducing GHG emission in shipping, it also explains about the strength, weakness and various implications towards shipping company. Shipping industry contributes around 3% of global GHG emission and roughly emits around 1 billion tons of CO₂ into the atmosphere which is significant and it contributes to climate changes. The reduction of GHG from ship is the key for decarbonizing shipping industry. This chapter reviews the regulations of IMO and EU for reducing GHG emission in shipping, it also explains about the strength, weakness and various implications towards shipping company.

3.1 IMO MEASURES

In 2018, IMO has devised an Initial plan for decreasing GHG emission in shipping sector during 72nd session of MEPC. It was adopted under MARPOL and the certification EEDI and SEEMP to reduce GHG emission are made mandatory for all the ships over 400 GT.

3.2 EEDI & SEEMP

The EEDI index has established a bottom technical competence threshold of Carbon emissions (grams) per tonne-mile, which is based on the kind of ship. It is comparable to the vessel efficiency index and applies globally, regardless of where vessel is built or operated or its flag state. It is left open to the shipping industry level of its success (Regulation 21 MARPOL Annex VI). On the other hand SEEMP has no standard indicators but it implies operational efficiency with respective energy rating. It provides industry with recommendations for guiding principles in fuel-efficient ship operation, propeller maintenance, and waste heat system recovery.

3.3 IMO INITIAL PLAN 2018

The GHG initial plan 2018 has been drafted by IMO as it set various goals and various stakeholders' measures. This strategy has set 2023 as the deadline for its revision which is very widely seen as the first line where mandatory IMO regulations may emerge into force. This strategy has its root from 2015 Paris agreement, in spite it has excluded international shipping from its action plan.

The summary of IMO GHG Plan is as follows:

-
1. This includes collectively reviewing and improvising the EEDI requirements for various categories of ships.
 2. Its main scope is to drastically reduce carbon emission from various vertical of shipping industry by reducing by 40% by target year of 2030 and pursuing forward its aim to further reduce it to 70% by 2070 taking base year as 2008.
 3. To peak various steps to decrease GHG emission from worldwide shipping on priority basis and to drastically reduce the annual Greenhouse Gas emission by 50% by 2050 by taking base year as 2008.

In terms of the first goal, MEPC 75 decided in November 2020 to draughts revisions to MARPOL Annex VI, moving EEDI phase 3 requirements from 2025 to 2022. (These should now be adopted at the MEPC 76 meeting in June 2021.)

The measurements provided are separated into three categories: short-term, mid-term, and long-term. The short term is defined as the period from 2018 to 2023, the medium term as the period from 2023 to 2030, and the long term as the period after 2030. Candidates' short-term actions include a mix of technology, operational, and regulation solutions.

3.4 NON-IMO MEASURES: EU MRV REGULATION & EU ETS

The EU-MRV Regulation (EU) 2015/757 "lays down rules for the accurate tracking, revealing, and validation of CO₂ emissions as well as other associated facts from ships arriving at, inside, or leaving ports under the authority of a Member State in order to support the cost-effective reduction of Carbon emissions from marine transport." The EU Parliament

accepted a draught modification to the EU MRV on September 16, 2020. Shipping is now explicitly included in the EU ETS, which must now be approved by the EU Council as a result of this proposed amendment. The EU ETS is the world's first and largest carbon market, operating on a "cap and trade" model. GHG emissions are capped overall, and the cap is gradually dropped, causing total emissions to diminish.

On the other hand, the EU Commission wants not to merge the EU ETS with the EU MRV, and intends to present its own plan for inclusion in the EU ETS based on the European Green Deal in 2021. The Commission must also decide whether expenditures are borne by proprietors or charterers. The EU Council, which represents EU member states, must approve either the Commission's, or the State legislature plan, and the related talks are not scheduled to be completed until 2022. In addition, the Commission is contemplating modifying regulations that might increase ship-side electricity (SSE) delivery to port facilities (Alternative Energy Infrastructure Directive, Energy Taxation Directive), such as legislation requiring SSE infrastructure at cruise and cargo terminals and exempting SSE from municipal taxes for a transition period.

The cost of eliminating shipping emissions is expected to reach \$1.65 trillion by 2050. Shipping relies on huge, lengthy assets and a consistent supply of fuel to meet the industry's annual requirement of 12 exajoules.

Reduced shipping emissions are an important, challenging, and costly endeavor. Regulation is typically considered as a need and the most powerful motivation for completing the task. So far, the IMO has approved fuel performance and operational rules like the EEDI and SEEMP, as well as produced an Action Plan with proposed measures that are not yet legally binding. The EU wants to go far further, legally requiring a 40% reduction in CO₂ emissions by 2030 and incorporating shipping in the EU carbon market, which is opposed by numerous major organizations and states. Whether global or local legislation eventually wins is critical to shipping businesses' present and long-term goals.

3.5 EU MRV

The EU MRV rule requires shipping companies with vessels of more than 5,000 GT operating in the EU to develop tracking plans outlining how they will track and publish their carbon dioxide emissions and transport work by August 2017. The EU will collect and make public data on over 12,000 commercial ships that stop at EU ports on or after January 1, 2018, to load or unload commodities or passengers. Every ship, regardless of flag or origin, is required to measure and record its fuel use and CO₂ emissions. The associated transport task, which is calculated by multiplying the commercial commodities transferred by the distance sailed, must also be reported. Ballast transport must be handled the same as laden transit. Only battleships, naval auxiliary ships, and a few specialized ships are exempted.

3.6 THE AIM AND OBJECTIVES OF THE MANAGEMENT PLAN

Any vessel that plans to make a business call at an EU port in 2018 must have a monitoring plan (MP). According to Article 6 of the EU MRV Regulation, the following things must be contained in this MP:

- Identification of exhaust emissions
- Identification of the ship and shipping company / vessel owner
- Description of techniques for tracking trips, fuel consumption, and activity data
- Methodology for addressing data gaps Procedures for quality control
- Identification of duties and deployment of ICT systems

The MP must specify which of the four permissible emissions monitoring procedures (timely stock availability of fuel tanks and the Bunker delivery note (BDN), Bunker fuel tank monitoring on board, monitoring the flow of fuel into the combustion chamber, or the setup to actually quantify the emission) the shipping company intends to use, as well as how transport work will be computed. Before the first observation period begins, it must be presented to the verification authority by August 31st, 2017 and successfully assessed by

December 31st, 2017. After that, the 2018 emissions and transportation work data must be combined into an annual report that must be certified by an external certified verifier by April 30, 2019. Following that, the report must be submitted to the EU Commission and the Flag State, and the ship must carry the compliance document commencing in June 2019. Although the first statutory timeframe of August 31, 2017 is still eight months away, MRV planning may begin now because most of the technical regulations have already been legally agreed upon.

3.7 IMO FUEL CONSUMPTION DATA COLLECTION SYSTEM

The International Maritime Organization (IMO) has taken a global approach, introducing a mandatory fuel consumption data collection system for international shipping, with ships of 5,000 GT and above having to start receiving and reporting data to an IMO database in 2019. As a change to Chapter 4 of MARPOL Annex VI, a new Regulation (22A) on the collection and reporting of vessel fuel oil usage statistics has been enacted. Furthermore, additional appendices covering 'Information to be provided to the IMO, including 'Ship Fuel Oil Consumption Database' (Appendix IX), and 'Form of Statement of Compliance – Fuel Oil Consumption Reporting' have been produced (Appendix X). These changes will become effective on March 1, 2018, with the first reported period spanning the calendar year 2019.

After the end of each calendar year, aggregated data must be supplied to the vessel's flag state, which must validate that the data was reported in accordance with Annex VI criteria before issuing the ship a Statement of Compliance. Following that, administrations will provide anonymised data to the IMO Vessel Fuel Oil Consumption Database. Fuel usage (by fuel type and in metric tonnes), distance travelled, and time spent at sea (from berth to berth) must all be provided.

Furthermore, flag administrations or other approved institutions must confirm that, by December 31, 2018, the Ship Energy Efficiency Management Plan (SEEMP) hands on deck has been revised to specify the techniques that will be used for gathering the required data and disclosing that data to the flag administration.

The SEEMP Guidelines have been revised, providing direction for creating the methods to be utilized for data collecting and reporting, as well as defining the data that must be acquired. The needed data collection approach is intended to be the first of three stages in which data analysis will serve as the foundation for an objective, transparent, and inclusive MEPC policy debate. This will be followed by a final agreement on goals and activities, as well as a plan for implementation in 2023.

3.8 EU MRV AND IMO FUEL DATA SYSTEMS COMPARED

Table 3.1 EU-MRV Vs IMO DCS

	EU MRV Regulation	IMO DCS
Entry into Force	1-Jul-15	1-Mar-18
Scope	Ships above 5000 GT Voyages to/from EEA ports of call	Ships above 5000 GT International Voyage
First Monitoring Period	2018	2019
Procedures	Monitoring Plan (37 Section)	Data Collection Plan (SEEMP Part II) (9 Section)
Compliance (procedures)	Assessment Report	Confirmation of Compliance
Reporting	Fuel Consumption Carbon Emission Transport Work Distance sailed Time at sea excluding anchorage	Total fuel consumption Distance travelled Hours underway Design deadweight used as proxy
Verification	Independent accredited verifiers	Flag administrations or Authorized Organizations
Compliance (reporting)	Document of Compliance (June 2019)	Statement of Compliance (May 2020)
Publication	Distinctive public database	Anonymous public database

(Source-Verifavia Shipping)

The table 3.1 above compares the important ingredients of the two programs side - by - side for ease of comparison. The following are the significant distinctions:

-
- The EU MRV Act demands reporting of actual products transported on-board, gasoline consumption, and CO₂ emissions, but the IMO just needs reporting of fuel consumed. Shipping companies calculate EU MRV and get it certified by an authorised verifier. The administration checks the IMO computations in conformity with national standards.
 - While the EU aims to make this information public, the IMO intends to make raw data available only to the IMO and flag states, who will thereafter share aggregated anonymized data.

3.9 FUTURE DEVELOPMENT

Shipping emissions are predicted to climb by 50 to 250 % by 2050, depending on future economic and energy improvements. If global targets of keeping global warming below 2 degrees Celsius are to be maintained, this rate of increase must be moderated, particularly in light of the Paris Agreement, and the global maritime community recognises that it must pay its "fair share" to efforts to cut GHG emissions. Ships of 5,000 GT and greater are expected to account for around 85 % of Carbon dioxide emissions from international shipping, which is why both the IMO and EU regimes apply to such vessels.

The EU MRV system was intended to contribute to the development of a worldwide system, and requests for alignment are still being made. At the moment, it is uncertain if this will occur. However, it is evident that the EC requires the IMO regulations to be published before proceeding with any public consultation, so that all needed info on the operation of the IMO data collection system is available. This will take time, as with any new sophisticated method or rule, so the two systems will almost certainly operate in parallel for the foreseeable future.

Although the industry is worried about "Name and Shame" and does not want two different systems, the European Parliament believes the IMO system is less open and accurate than the European one. Both standards must be met by vessels calling at European ports in 2019 and beyond.

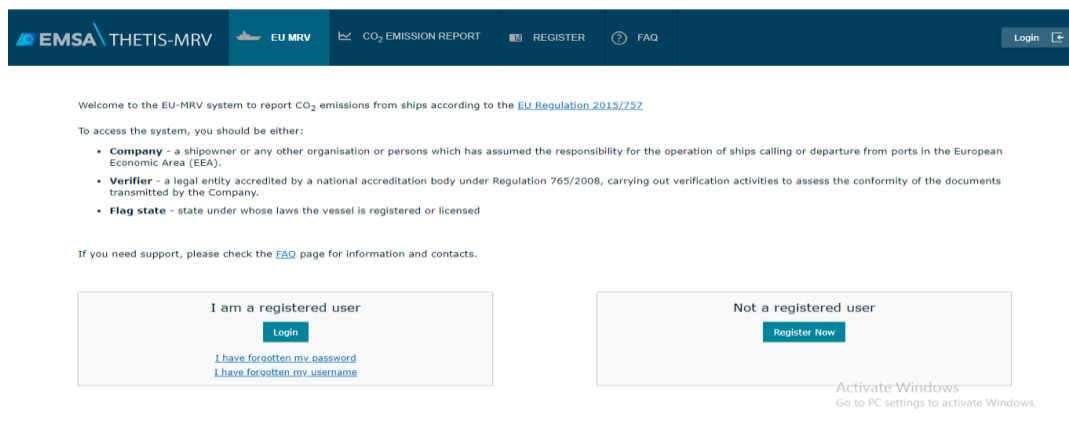
Even if some harmonization of the two systems happens in the future, ship operators should prepare for the first MRV deadline of August 31, 2017. Gaps can be identified and closed in a timely manner by examining vessel monitoring and reporting duties, as well as onshore systems and processes, to guarantee timely and effective compliance.

Chapter - IV

ANALYSIS OF EMISSION DATASET WITH DIFFERENT STATISTICAL MODEL

4.1 COLLECTION OF DATA

Fig 4.1- THETIS MRV WEBSITE



(Source-THETIS-MRV)

The emission dataset of various ships sailing through European waters for 2018, 2019, 2020 reporting year is collected from THETIS-MRV website. The data for those reporting year are updated by shipping company as per EU CO₂ emission monitoring regulation Article 21 of Regulation (EU) 2015/757 it was reviewed by the verifier's accredited by EU Member States.

4.2 DATA ANALYSIS

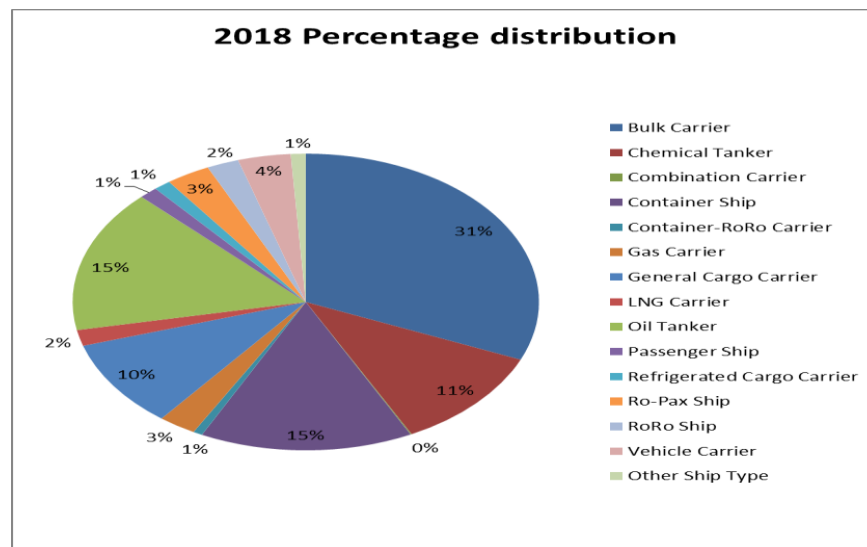
The collected data from THETIS-MRV website are then validated by various statistical tools as mentioned below,

- Percentage distribution analysis
- Avg. CO₂ emission Vs Avg.Fuel consumption analysis
- Descriptive statistical analysis
- Regression analysis for the reporting year 2019 both consolidated and random sampling.

4.3 PERCENTAGE DISTRIBUTION ANALYSIS OF VARIOUS CATEGORIES OF SHIP FROM 2018-2020

Method- The dataset for the reporting year 2018-2020 has been collected from THETIS-MRV and then analyzed for the percentage distribution of various categories, which are listed below.

Chart 4.1- Percentage of ship categories in the year 2018



(Source-THETIS-MRV)

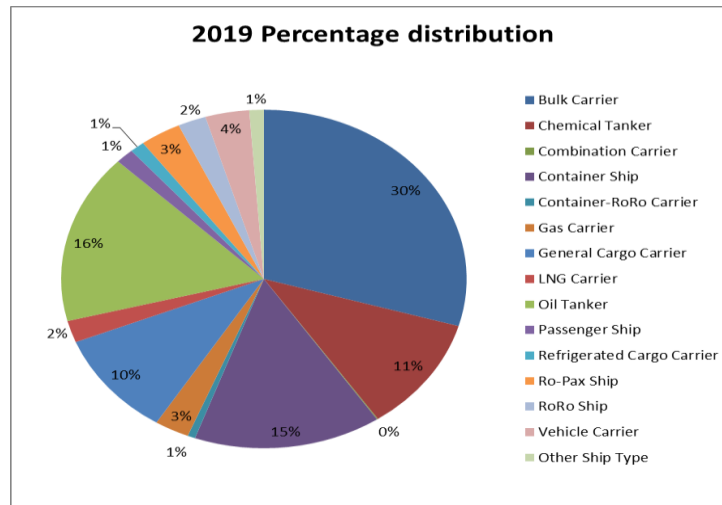
Table 4.1- Breakup of various ship categories 2018

S.NO	Ship Category	Total
1	Bulk Carrier	3839
2	Chemical Tanker	1364
3	Combination Carrier	10
4	Container Ship	1808
5	Container-RoRo Carrier	80
6	Gas Carrier	321
7	General Cargo Carrier	1176
8	LNG Carrier	213
9	Oil Tanker	1907
10	Passenger Ship	159
11	Refrigerated Cargo Carrier	145
12	Ro-Pax Ship	376
13	RoRo Ship	271
14	Vehicle Carrier	448
15	Other Ship Type	126
	Total	12243

(Source-THETIS-MRV)

Inference- In 2018 data 31% are bulk tankers, Oil tanker stands second with 15% and container ship stands third with 15 % the breakup percentage of various ship categories has been shown in chart and total breakup of various ship has been mentioned in table. Total ship sailed in EU in 2018 waters is around 12243 which have been analyzed in this report.

Chart 4.2- Percentage of ship categories in the year 2019



(Source-THETIS-MRV)

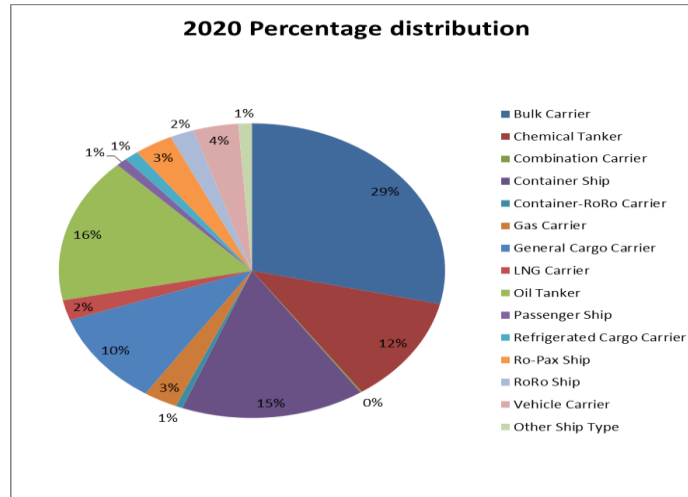
Table 4.2- Breakup of various ship categories 2019

S.NO	Ship Type	Total
1	Bulk Carrier	3650
2	Chemical Tanker	1362
3	Combination Carrier	11
4	Container Ship	1850
5	Container-RoRo Carrier	76
6	Gas Carrier	342
7	General Cargo Carrier	1242
8	LNG Carrier	257
9	Oil Tanker	2008
10	Passenger Ship	179
11	Refrigerated Cargo Carrier	145
12	Ro-Pax Ship	403
13	RoRo Ship	277
14	Vehicle Carrier	434
15	Other Ship Type	142
Total		12378

(Source-THETIS-MRV)

Inference- In 2019 data 30% are bulk tankers, Oil tanker stands second with 16% and container ship stands third with 15 % the breakup percentage of various ship categories has been shown in chart and total breakup of various ship has been mentioned in table. Total ship sailed in EU waters in 2019 is around 12378 which have been analyzed in this report.

Chart 4.3- Percentage of ship categories in the year 2020



(Source-THETIS-MRV)

Table 4.3- Breakup of various ship categories 2020

S.NO	Ship Type	Total
1	Bulk Carrier	3446
2	Chemical Tanker	1350
3	Combination Carrier	15
4	Container Ship	1851
5	Container-RoRo Carrier	70
6	Gas Carrier	343
7	General Cargo Carrier	1232
8	LNG Carrier	267
9	Oil Tanker	1921
10	Passenger Ship	111
11	Refrigerated Cargo Carrier	144
12	Ro-Pax Ship	389
13	RoRo Ship	242
14	Vehicle Carrier	454
15	Other Ship Type	136
	Total	11971

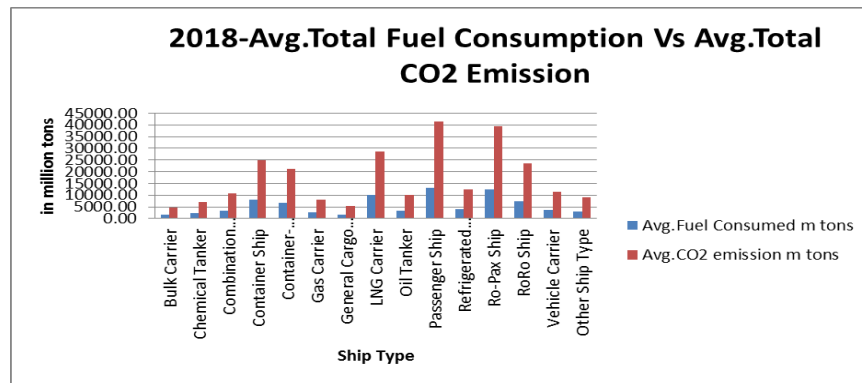
(Source-THETIS-MRV)

Inference- In 2020 data 29% are bulk tankers, Oil tanker stands second with 16% and container ship stands third with 15 % the breakup percentage of various ship categories has been shown in chart and total breakup of various ship has been mentioned in table. Total ship sailed in EU waters in 2020 is around 11971 which have been analyzed in this report.

4.4 AVERAGE CO₂ EMISSION Vs AVG. FUEL CONSUMPTION FOR VARIOUS SHIP CATEGORIES FROM 2018-2020

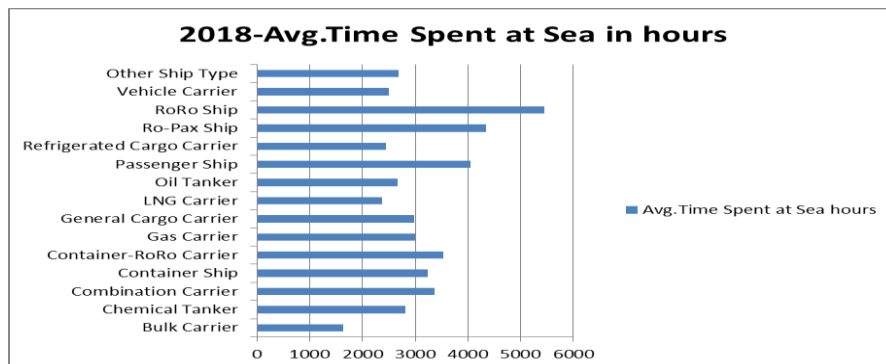
Method- The data collected from THETIS-MRV for the reporting year 2018, 2019, and 2020 has been used to calculate the mean values of each categories of ship. The variables considered in this analysis are Total Fuel Consumption in m tonnes, Total CO₂ Emission in m tonnes and Total time spent at sea in hours.

Chart 4.4- Average Fuel Consumption Vs Average CO₂ Emission of ship categories in the year 2018



(Source-THETIS-MRV)

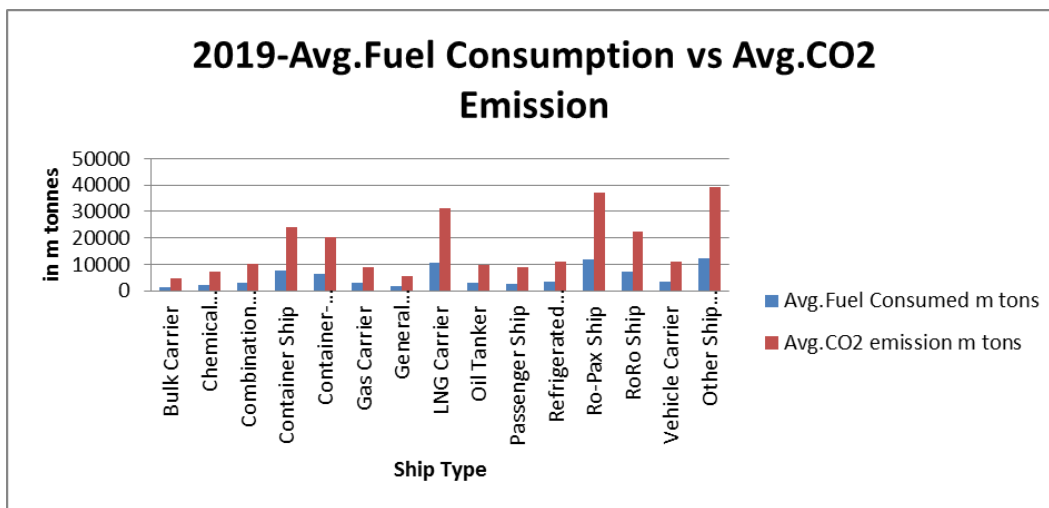
Chart 4.5- Average Time spent at sea in hours of ship categories in the year 2018



(Source-THETIS-MRV)

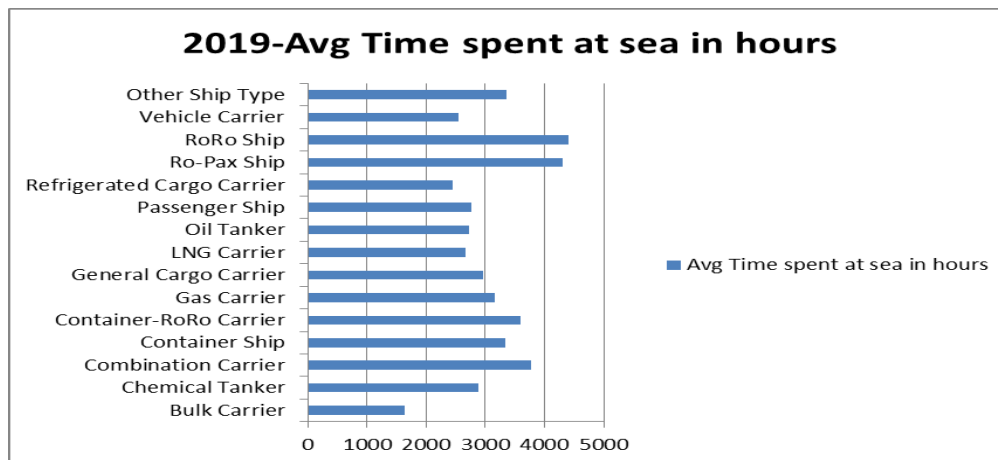
Inference- Analyzing 2018 data passenger ship stands first in CO₂ emission it emits an average of 40,000 million tonnes of CO₂ annually into atmosphere. Second is RO-Pax ship category which emits an average of 38000 million tonnes of CO₂ annually into the atmosphere. But both the ship categories are less in numbers when we consider other ship categories. On considering average time spent at sea RO-RO ships stands first which spends an average more than 5000 hours at sea annually and RO-Pax ships stands second which spends an average more than 4000 hours at sea annually.

Chart 4.6- Average Fuel Consumption Vs Average CO₂ Emission of ship categories in the year 2019



(Source-THETIS-MRV)

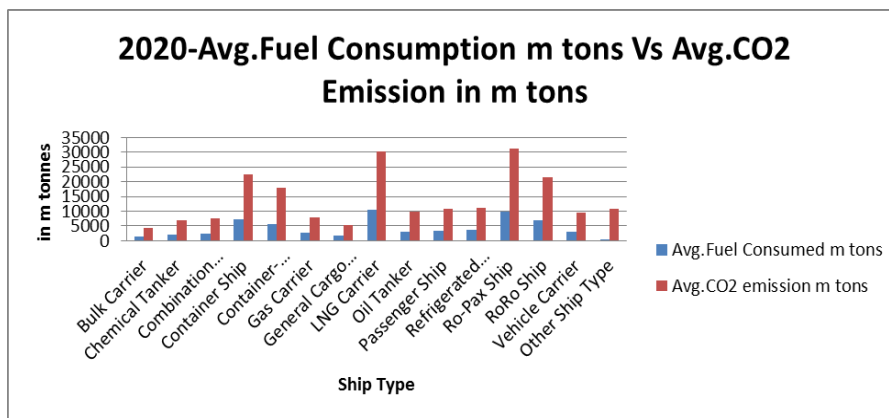
Chart 4.7- Average Time spent at sea in hours of ship categories in the year 2019



(Source-THETIS-MRV)

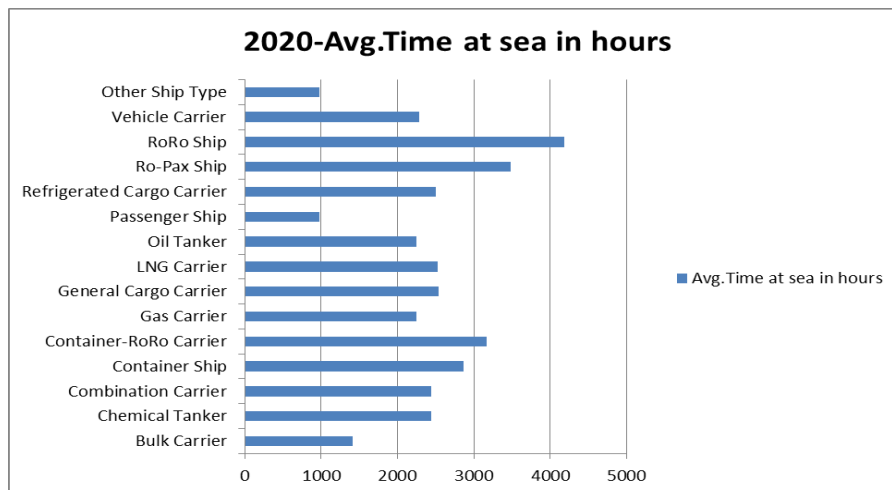
Inference- Analyzing 2019 data other ship stands first in CO₂ emission it emits an average of 39,000 million tonnes of CO₂ annually into atmosphere. Second is RO-Pax ship category which emits an average of 37,000 million tonnes of CO₂ annually into the atmosphere. But both the ship categories are less in numbers when we consider other ship categories. On considering average time spent at sea RO-RO ships stands first which spends an average more than 4500 hours at sea annually and RO-Pax ships stands second which spends an average more than 4300 hours at sea annually.

Chart 4.8- Average Fuel Consumption Vs Average CO₂ Emission of ship categories in the year 2020



(Source-THETIS-MRV)

Chart 4.9- Average Time spent at sea in hours of ship categories in the year 2020



(Source-THETIS-MRV)

Inference- Analyzing 2020 data Ro-Pax ship stands first in CO₂ emission it emits an average of 31,000 million tonnes of CO₂ annually into atmosphere. Second is LNG Carrier ship category which emits an average of 29,000 million tonnes of CO₂ annually into the atmosphere. But both the ship categories are less in numbers when we consider other ship categories. On considering average time spent at sea RO-RO ships stands first which spends an average more than 4000 hours at sea annually and RO-Pax ships stands second which spends an average more than 3500 hours at sea annually.

4.5 GROWTH RATE OF CO₂ EMISSION FROM 2019-2020 CONSIDERING 2018 AS BASE YEAR

Method- The data collected from THETIS-MRV for reporting year 2018, 2019 and 2020. On considering 2018 as base year and have calculated growth rate in % for the variables Total Fuel Consumption in million tonnes, Total CO₂ Emission in million tonnes, Total Time Spent at Sea in hours and the total number of ships.

Table 4.4- Growth Rate Analysis

Variables		Year		
		2018	2019	2020
Total fuel consumption [m tonnes]	Value in m tons	46485468.74	47062463.55	41122133
	Growth Rate in %	-	1.24%	-11.54%
Total CO ₂ emissions [m tonnes]	Value in m tons	145202092.9	146902136.6	128267790.7
	Growth Rate	-	1.17%	-11.66%
Annual Total time spent at sea [hours]	Value in hours	31928987.75	32659405.6	26817735.41
	Growth Rate in %	-	2.28%	-16%
Total No. Ships	Value in nos	12243	12378	11971
	Growth Rate in %	-	1.10%	-2.22%

(Source-THETIS-MRV)

Inference- Total fuel consumption in million tonnes in 2018 stands at 46485468.74 and in 2019 it is at 47062463.55 with a growth rate of 1.24% and in 2020 it stands at 41122133 with a negative growth rate of 11.54%. Total CO₂ Emission in million tonnes in 2018 stands at 145202092.9 and in 2019 it is at 146902136.6 with a growth rate of 1.17% and in 2020 it stands at 128267790.7 with a negative growth rate of 11.66%. Total Time Spent at Sea in hours in 2018 stands at 31928987.75 and in 2019 it is at 32659405.6 with a growth rate of 2.28% and in 2020 it

stands at 26817735.41 with a negative growth rate of 16%. Total No. Ships sailed in European waters in 2018 are 12243 and in 2019 its 12378 with a growth rate of 1.10% and in 2020 it is 11971 with a negative growth rate of 2.22%.

4.6 DESCRIPTIVE STATISTICAL ANALYSIS (2018-2020)

Method- The data collected from THETIS-MRV for the reporting year 2018, 2019, 2020 and basic statistical tools like mean, SE mean, Standard Deviation, Median, Minimum-Maximum and First Quartile-Third Quartile has been derived.

Table 4.5- Descriptive statistics for reporting year 2018

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
Total Fuel Consumed m tons	12243	0	3796.6	45.1	4986	0	1052.5	2132.4	4302.7	98465.2
Total CO ₂ emission m tons	12243	0	11859	140	15509	0	3300	6669	13498	315479
Total time Spent at Sea hours	12243	0	2608	28.4	3145	0	1047	2133	3929	276023

(Source-THETIS-MRV)

Inference- The total number of ships is 12243 in 2018 with an average of Total Fuel Consumption in million tonnes of 3796.6 and average Total CO₂ emission in million tonnes is 11859 and average Total Time at Sea is 2608 hours. Median for those three variables is 2132.4, 6669, 2133 respectively. The Standard Deviation for those variables is 4986, 15509, 3145 respectively. First Quartile value for those variables, where it explains the mean value of first 25% of data is 1052.5, 3300, 1047 and Third Quartile value for those variables, where it explains the mean value of first 75% of data is 4302.7, 13498, 3929. The Maximum value for those variables is 98465.2, 315479, and 276023. The Minimum value for those variables is 0 in all categories.

Table 4.6- Descriptive statistics for reporting year 2019

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
Total fuel consump [m tonnes]	12378	0	3802.1	42.2	4695.2	0	1129	2194.6	4351.2	48449.6
Total CO2 emission m tons]	12378	0	11868	131	14542	0	3536	6886	13684	151825
Total time at sea hours	12378	0	2638.5	16.6	1848.4	0	1137.7	2223.1	3946.9	26794

(Source-THETIS-MRV)

Inference- The total number of ships is 12378 in 2019 with an average of Total Fuel Consumption in million tonnes of 3802.1 and average Total CO₂ emission in million tonnes is 11868 and average Total Time at Sea is 2638.5 hours. Median for those three variables is 3802.1, 11868, and 2638.5 respectively. The Standard Deviation for those variables is 4695.2, 14542, 1848 respectively. First Quartile value for those variables, where it explains the mean value of first 25% of data is 1129, 3536, 1137.7 and Third Quartile value for those variables, where it explains the mean value of first 75% of data is 4351.2, 13684, 3946.9. The Maximum value for those variables is 48449.6, 151825, and 26794. The Minimum value for those variables is 0 in all categories.

Table 4.7- Descriptive statistics for reporting year 2020

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
Total CO2 emissions [m tonnes]	11971	0	10709	119	13035	0	3202	6394	12444	151141
Total fuel consump [m tonnes]	11971	0	3433.1	38.6	4229.9	0	1016.9	2031	3964.8	48499.5
Total time at sea hours	11971	0	2238.9	14.5	1589.9	0	948.9	1863.7	3315.7	8603.5

(Source-THETIS-MRV)

Inference- The total number of ships is 11971 in 2020 with an average of Total Fuel Consumption in million tonnes of 3433.1 and average Total CO₂ emission in million tonnes is 10709 and average Total Time at Sea is 2238.9 hours. Median for those three variables is 6394, 2031, 1863.7 respectively. The Standard Deviation for those variables is 13035, 4229.9, and 1589.9 respectively. First Quartile value for those variables, where it explains the mean value of first 25% of data is 3202, 1016.9, 948.9 and Third Quartile value for those variables, where it explains the mean value of first 75% of data is 12444, 3964.8, and 3315.7. The Maximum value for those variables is 151141, 48499.5, and 8603.5. The Minimum value for those variables is 0 in all categories.

4.7 REGRESSION ANALYSIS

Method- The dataset of 2019 has been taken from THETIS-MRV and considered for regression analysis and Durbin-Watson Statistic, which was done using Minitab Statistical Software. Total of two regression analysis has been derived to find out which variable is significant in CO₂ emission.

Regression 1- Complete data of 2019 is considered and Regression Analysis is performed Total CO₂ emissions m tonnes versus Total time at sea hours, Total fuel consump m tonnes, Technical effi (gCO₂/t·nm).

Equation Model: $Y = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots + \epsilon$

Where Y is Total CO₂ emissions m tonnes which is dependent variable, β_i is the slope of X_i (Independent Variable), X_1 is Total time at sea hours, X_2 is Total fuel consump m tonnes, X_3 is Technical effi (gCO₂/t·nm) and ϵ is the least value or error (its value is considered zero if regression line is true).

Regression 2- Random sampling using MS excel Approx 5% sample due to time constraint in collecting data of Age weightage for this sample has been given by % of different variety of ships as per Chart No. 4.2 and Dwt from Marine Traffic Website of Complete data of 2019 is considered and Regression Analysis is performed Total CO₂ emissions m tonnes versus Total fuel consump m tonnes, Total time at sea hours, Technical effi (gCO₂/t·nm), Age, Dwt.

Equation Model: $Y = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \dots + \epsilon$

Where Y is Total CO₂ emissions m tonnes which is dependent variable, β_i is the slope of X_i (Independent Variable), X_1 is Total fuel consump m tonnes, X_2 is Total time at sea hours T, X_3 is

Technical effi (gCO₂/t·nm), X₄ is Age in years, X₅ is Dwt in tonnes and ε is the least value or error (its value is considered zero if regression line is true).

ANALYSIS- REGRESSION 1

Regression Analysis: Total CO₂ emissions m tonnes versus Total time at sea hours, Total fuel consump m tonnes, Technical effi (gCO₂/t·nm)

Regression Equation

$$\begin{aligned} \text{Total CO}_2 \text{ emissions m tonnes} &= 0.04913 \text{ Total time at sea hours} \\ &+ 3.08452 \text{ Total fuel consump m tonnes} \\ &+ 0.248 \text{ Technical effi (gCO}_2\text{/t·nm)} \end{aligned}$$

Coefficients

Table 4.8- Co-efficients of Regression Analysis 1

Term	Coef	SE Coef	T-Value	P-Value	VIF
Total time at sea hours	0.0491	0.00279	17.6	0	2.19
Total fuel consump m tonnes	3.0845	0.00152	2032.01	0	2.15
Technical effi (gCO ₂ /t·nm)	0.248	0.147	1.68	0.093	1.07

(Source-THETIS-MRV)

Model Summary

Table 4.9- Model Summary of Regression Analysis 1

S	R-sq	R-sq(adj)	R-sq(pred)
696.339	99.86%	99.86%	99.86%

(Source-THETIS-MRV)

Analysis of Variance

Table 4.10- Variance from Regression Analysis 1

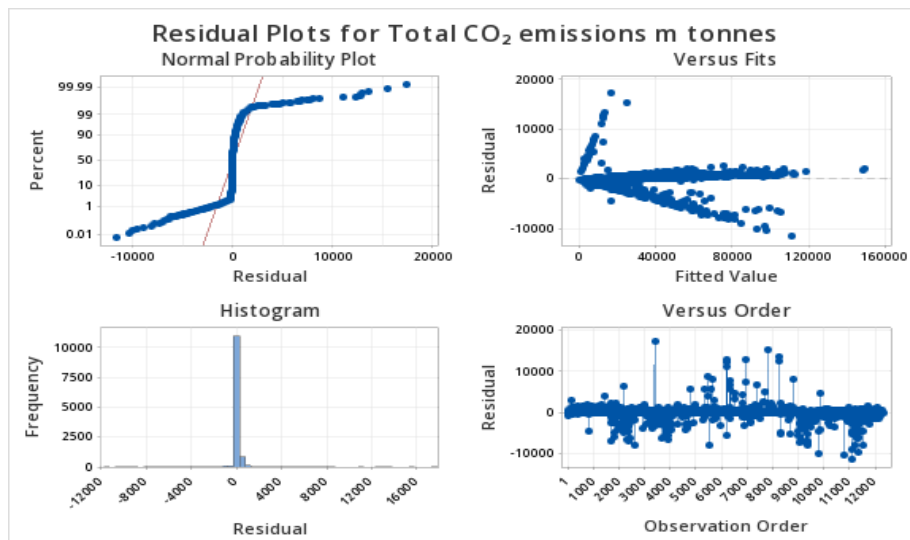
Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	4.35E+12	1.45E+12	2993687.71	0
Total time at sea hours	1	15016442 3	15016442 3	309.69	0
Total fuel consump m tonnes	1	2.00E+12	2.00E+12	4129056.14	0
Technical effi (gCO ₂ /t.nm)	1	1369526	1369526	2.82	0.093
Error	12375	6E+09	484888		
Lack-of-Fit	12245	6E+09	490036	*	*
Pure Error	130	0	0		
Total	12378	4.36E+12			

(Source-THETIS-MRV)

Durbin-Watson Statistic

Durbin-Watson Statistic =1.44119

Fig 4.2- Residual plots for total CO₂ emission in m tonnes for regression analysis 1



(Source-THETIS-MRV)

Inference- The regression for the dataset of 2019 shows all three variables Total time at sea hours, Total fuel consump m tonnes, Technical effi (gCO₂/t·nm) are very significant with respective to Total Carbon Emission In million tonnes. The P values of those three variables are 0, 0 and 0.093. A total of 12378 of ship data are considered. We can see the residual plot and fit in above img and the regression value is 0 so the entire regression is significant and null hypothesis is rejected. The Durbin-Watson value is 1.44119 which shows positive Co-Relation with the regression Variables.

Analysis - Regression 2

Regression Equation

$$\begin{aligned} \text{Total CO}_2 \text{ emissions m tonnes} &= 3.06074 \text{ Total fuel consumpm tonnes} \\ &+ 0.0340 \text{ Total time at sea hours} \\ &+ 3.18 \text{ Technical effi (gCO}_2\text{/t·nm)} + 8.90 \text{ Age} \\ &+ 0.000235 \text{ Dwt} \end{aligned}$$

Coefficients

Table 4.11- Co-efficients of Regression Analysis 2

Term	Coef	SE Coef	T-Value	P-Value	VIF
Total fuel consump m tonnes	3.06074	0.00887	345.05	0	2.32
Total time at sea hours	0.034	0.0223	1.52	0.129	3.82
Technical effi (gCO ₂ /t·nm)	3.18	4.08	0.78	0.436	3.13
Age	8.9	5.17	1.72	0.086	3.87
Dwt	0.000235	0.000606	0.39	0.699	1.6

(Source-THETIS-MRV)

Model Summary

Table 4.12- Model Summary of Regression Analysis 2

S	R-sq	R-sq(adj)	R-sq(pred)
908.826	99.78%	99.78%	99.77%

(Source-THETIS-MRV)

Analysis of Variance

Table 4.13- Variance from Regression Analysis 2

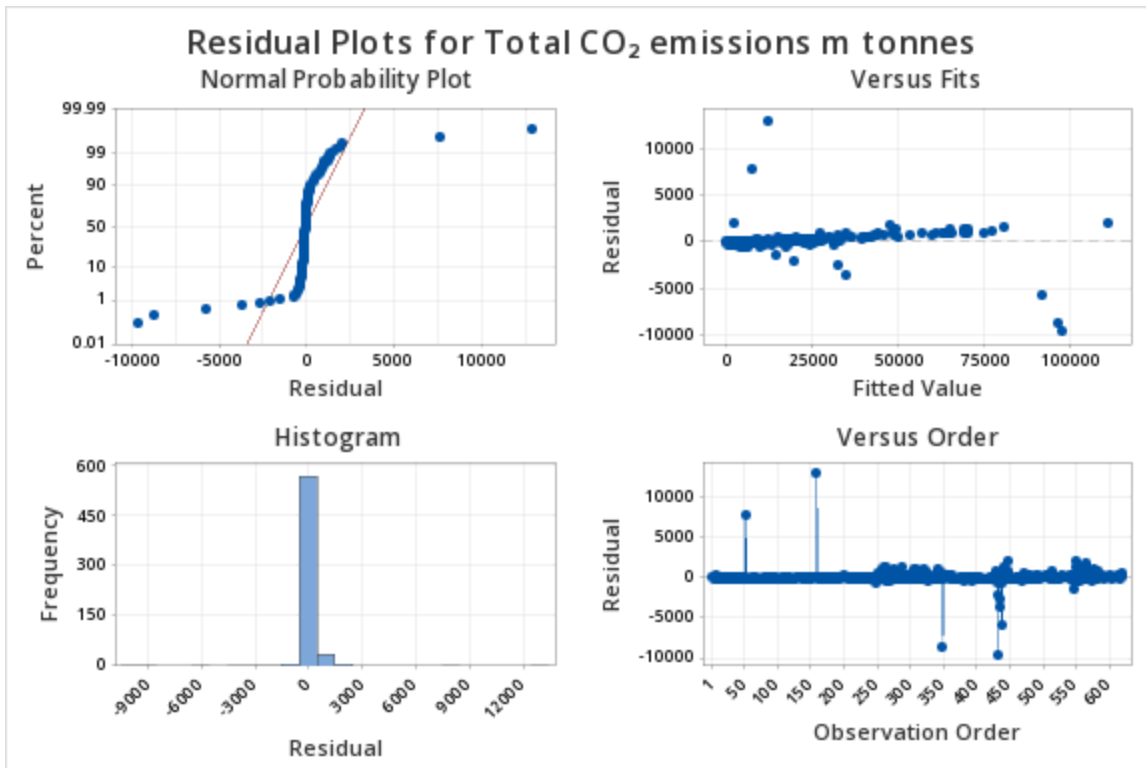
Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	5	2.33E+11	46516891495	56318.2	0
Total fuel consump m tonnes	1	9.834E+10	98337518021	119057.65	0
Total time at sea hours	1	1913246	1913246	2.32	0.129
Technical effi (gCO₂/t-nm)	1	501713	501713	0.61	0.436
Age	1	2446136	2446136	2.96	0.086
Dwt	1	123690	123690	0.15	0.699
Error	616	508794796	825966		
Lack-of-Fit	614	508794796	828656	*	*
Pure Error	2	0	0		
Total	621	2.33E+11			

(Source-THETIS-MRV)

Durbin-Watson Statistic

Durbin-Watson Statistic = 1.87599

Fig 4.3- Residual plots for total CO₂ emission in m tonnes for regression analysis 2



(Source-THETIS-MRV)

Inference- The regression for the dataset 5% sample of 2019 shows all two variables Total fuel consump m tonnes, and Age in years are very significant with respect to Total Carbon Emission In million tonnes. The P values of those variables are 0, 0.086. The variable of Total Time Spent at Sea in hours, Technical Efficiency and Dwt proved to be insignificant towards Carbon Emission. A total of 621 of ship data are considered. We can see the residual plot and fit in above img and the regression value is 0 so the entire regression is significant and null hypothesis is rejected for Total fuel consump m tonnes, and Age. The Durbin-Watson value is 1.87599 which shows positive Co- Relation with the regression variables.

Chapter - V

FINDINGS, SUGGESTION AND CONCLUSION

5.1 FINDINGS

Percentage distribution analysis of various categories of ship from 2018-2020

- In all three reporting years we can see top three spots are occupied by Bulk Carrier (Around 30%), Oil Tanker (around 15%) and Container Ship (15%). This takes a sum of 65%.
- While remaining ship categories equals to 45%.

Average CO₂ emission Vs Avg. Fuel Consumption for various ship categories from 2018-2020

- We can see average CO₂ emission in million tonnes we can see passenger ship and RO-Pax has taken top two spots in 2018.
- While in reporting year 2019 we can see RO-Pax and Other ships taken top two spot. In 2020 we can see RO-Pax and LNG Carrier has taken top two spot.
- This is mainly due to the impact of COVID-19.
- Since Emission and Fuel Consumption has positive relation same results mentioned above is applicable for all three reporting years.
- Total time spent at sea in hours for 2018 reporting year RO-RO ships and RO-Pax takes top two spots.
- Same results for total time spent at sea in hours can be seen for the reporting year 2019 and 2020.
- This brings us to the conclusion that Ro-Ro and Ro-Pax ships spends more time at sea because they cruise in slow speed compared to other ship categories. This is because their loading and unloading time in port is low so they cruise at low speed to save the fuel cost.

Growth Rate of CO₂ emission from 2019-2020 considering 2018 as base year

- Total fuel consumption in million tonnes in 2018 stands at 46485468.74 and in 2019 it is at 47062463.55 with a growth rate of 1.24% and in 2020 it stands at 41122133 with a negative growth rate of 11.54%. Total CO₂ Emission in million tonnes in 2018 stands at 145202092.9 and in 2019 it is at 146902136.6 with a growth rate of 1.17% and in 2020 it stands at 128267790.7 with a negative growth rate of 11.66%. Total Time Spent at Sea in hours in 2018 stands at 31928987.75 and in 2019 it is at 32659405.6 with a growth rate of 2.28% and in 2020 it stands at 26817735.41 with a negative growth rate of 16%. Total No. Ships sailed in European waters in 2018 are 12243 and in 2019 its 12378 with a growth rate of 1.10% and in 2020 it is 11971 with a negative growth rate of 2.22%.
- We can see that all three variables has positive growth rate in 2019 but in 2020 it has shown a negative trend this is mainly because of the impact of lockdown on various level due COVID-19 Pandemic and slower port operation due to lack in manpower and social distancing.

Regression-

- The regression analysis for 2019 is considered because 2020 there is a COVID-19 effect in port operation and trade due to global lockdown.
- The regression analysis of consolidated data set of 2019 suggest that Total time spent at sea in hours, Total Fuel Consumption in million tonnes and Technical Efficiency has a significant role in determining the Total CO₂ emission.
- The Durbin-Watson value is 1.44119 which shows positive Co- Relation with the regression Variables.
- The regression analysis of 5% sample showed Age, Total Fuel Consumption in Million Tonnes is significant with respective Total CO₂ Emission in million tonnes. Where Total Time Spent at Sea, Dwt and Technical Efficiency proved to be insignificant this may be due to small set of data which represented from a whole set of data.
- The Durbin-Watson value is 1.87599 which shows positive Co- Relation with the regression variables.

5.2 SUGGESTIONS

- On reviewing both IMO and EU regulations towards GHG emission reduction there is no clarity how the energy transaction from fossil fuel to green fuel will happen. There is no significant pressure from such international bodies towards various stakeholders around the world to take innovative green technologies in hand. Innovative based incentives need to be considered to fasten such transaction to achieve the carbon net zero within stipulated timeline.
- There is no concrete data or study to determine the cost effectiveness of that energy transaction plan. Since the reduction of pollution need to be upscaled in various verticals of maritime sector, there is no clear model to achieve the GHG emission target within proposed timeline of 30 years period. This need to be considered and suitable model need to be created to achieve the target which should be economically feasible.
- EU has devised a stringent regulatory policy and mandated data collection through MRV, where it evaluates and ship which emits pollution more than threshold will be fined. Yet the regulation from IMO are not very strong towards the various stakeholders to increase the interest of various vessel owners and shipbuilding yard to consider modern green technologies and innovative technologies that can greatly contribute towards the reduction of GHG emission.
- As of now there is a double data collection system one is IMO DCS and other one is EU-MRV. Both need to be merged to consolidate various key parameters in determining CO₂ emission from ship.
- The transparency of data to the public population is given only by EU-MRV; the data from IMO DCS are protected from public only administrator can access this need to be changed, when it is made available to large population of researchers IMO can get various key suggestions and innovative plans to work towards the reduction of GHG emission.
- This report shows the fuel consumption, total time spent at sea and age is very significant parameters towards CO₂ emission. So the fuel consumption need to be reduced to reduce the GHG emission, this is possible only by introducing feasible and economical transaction plan from fossil fuel to green energy source.

- As per this report we have seen the emission from passenger, RO-Pax, Ro-Ro ship is very high compared to other categories of vessel so technologies need to be implemented to reduce the CO₂ emission in those ship categories which will have a positive note towards the GHG reduction plan. Yet the population of Bulk, Oil Tanker and Container Carriers are more than above mentioned ship it also need to be taken care.
- The certification plan like CII, EEDI and SEEMP are to be made stringent with effective reporting and evaluation so that there won't be any loop hole for stakeholders to escape by showing false reports.

5.3 CONCLUSION

The project “**A STUDY ON GHG EMISSION IN SHIPPING SECTOR AND THE ROLE OF EU & IMO REGULATIONS TOWARDS GHG REDUCTION**” tried to determine various variables which influence the CO₂ emission in ship. Various significant parameters are explained and the review of regulation policies of IMO and EU gives a broad view for the areas to improve to achieve net zero carbon emission within stipulated timeline.

The findings shows the relevance of various significant parameters such as total fuel consumption in million tonnes, age, total time spent at sea in hours and how those parameters affects the emission of CO₂ emission from ship. It is noted that usage innovative green technologies in shipping across various verticals should be incentivized which in turn increase the interest of various stakeholders to adopt it. The more clear regulations towards GHG emission reduction need to be made stringent and an economical model need to be created with stringent time line. Double data collection should be avoided and should be made transparent and accessible to all public in order to make effective use of those datasets. More importance should be given to the ship categories which is prominent in international shipping and emit more CO₂ compared to other ship categories.

This is the time to start an effective plan, stringent certification to reduce the GHG emission and all stake holders should support the international bodies in their fight against climate change.

The goal of this project is to find the effectiveness of IMO vs EU regulation and to device statistical model to find the significant variables which contributes towards CO₂ emission which has been explained in various chapter above.

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