MTCC ASIA
Maritime Technology Cooperation Centre

GMN The Global MTCC Network
A global network for energy-efficient shipping

GUIDELINES ON SHIP TRIM OPTIMIZATION

—BASED ON MACHINE LEARNING METHOD

Maritime Technology Cooperation Centre for Asia
(MTCC-Asia)

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Preface

The International Maritime Organization (IMO) and the European Commission (EC) reached an agreement in December 2015 to establish and seed-fund a global network of five Maritime Technology Cooperation Centres (MTCCs) in developing countries in the framework of the “Capacity Building for Climate Mitigation in the Maritime Shipping Industry” Project, with a funding contribution from the European Union (EU).The concept of establishing a global network of MTCCs to accelerate capacity building and technology transfer in the maritime field arose in response to a resolution (MEPC.229(65)) adopted by IMO in 2013, on “Promotion of Technical Co-operation and Transfer of Technology relating to the Improvement of Energy Efficiency of Ships”.

The overall objective of the Project is to support selected developing countries in limiting and reducing greenhouse gas (GHG) emissions from their shipping sector through technical assistance/capacity-building to promote low-carbon and energy efficient shipping technologies and operations. More specifically, the Project aims to establish five MTCCs, one in each of the target regions (Asia, Africa, the Caribbean, Latin America and the Pacific), which would act as centres of excellence to promote the uptake of low-carbon technologies in maritime transport.

Shanghai Maritime University (SMU) was selected as the host institution of MTCC for Asia (MTCC-Asia) in December 2016. Funded by the European Union and implemented by the IMO, MTCC-Asia under the guidance of the IMO Project Coordination Unit (PCU) is making every endeavor to achieve the above-mentioned objectives through a number of actions including pilot projects, regional and national workshops, international conferences, technical seminars, postgraduate program, branch offices, and dissemination activities.

This publication is one of the outputs under the framework of the clearly defined pilot project on “uptake of ship energy efficient technologies and operations”. It is well recognized that a variety of efficient operations during ship’s voyage can also make a noticeable contribution to improving the ship energy efficiency if ship operators and seafarers adequately implement those operations. MTCC-Asia prefers to encourage the ship to apply the trim optimization operation based on its obvious advantages, among which, there is no need to change ship structure or install additional devices; it can be easily achieved by adjusting the fore draft and aft draft manually or automatically; it neither reduces the ship cargo loading capacity and speed nor compromises the ship’s safety of machinery and cargo, and it can have remarkable effect in saving 2%-6% energy for ships.

Furthermore, with the development of artificial intelligent technology, the machine learning method compared to other traditional methods provides the shipping sector with a more accurate and efficient approach in applying the ship trim optimization operations. Relevant theoretical knowledge and practical cases presented in this publication have well demonstrated that the machine learning method is a reliable means to achieve the function of ship trim optimization operation provided that the past navigational data of the ship is available.

Besides the main purpose of providing overall knowledge and practices related to the ship trim optimization operation based on the machine learning method, more importantly, this publication also aims to raise the awareness of each practitioner in the shipping sector of better understanding the mission and the international regulatory framework developed under the leading role of the IMO for the reduction of GHG emissions from ships.

The contributions made towards the mission of reducing GHG emissions from ships rely not only on the marine regulators, maritime administrators and ship managers, but also on seafarers. As the front-line operator of a ship, each seafarer can play a direct and significant role in limiting or reducing GHG emissions from ships. To facilitate readers, in particular seafarers, this publication is written in a user friendly language through the avoidance of the complex terminology and formula as far as possible and is organized in five parts as follows:

- Chapter I presents the overall regulations developed and various actions conducted by IMO to enable the international shipping sector to meet the goal set in the United Nations Framework Convention on Climate Change (UNFCCC) for fighting the global climate change.

- Chapter II provides the basic theoretical knowledge regarding the ship trim optimization and machine learning method.

- Chapter III introduces in detail the operations of ship trim optimization based on the machine learning method, including the data preparation, system development and practical cases.

- Conclusions and precautions in operating ship trim optimization based on the machine learning method are summarized in Chapter IV.

- An operational guidance for users' reference on simplified software of ship trim optimization based on the machine learning method is demonstrated in Chapter V.

Comments and observations are welcome to be sent to the feedback contact information shown on the back cover of this publication.

MTCC-Asia
October 2019

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Abbreviations and Unit Symbols

℃	Celsius degree
CBDR	Common But Differentiated Responsibilities
CFD	Computational Fluid Dynamics
CH_4	methane
CO_2	carbon dioxide
EEDI	Energy Efficiency Design Index
EEOI	Energy Efficiency Operational Indicator
GHG	Greenhouse Gas
GloMEEP	Global Maritime Energy Efficiency Partnerships
GMN	Global MTCCs Network
GT	Gross Tonnage
HFO	Heavy Fuel Oil
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
kn	knot
kW	kilowatts
LNG	Liquefied Natural Gas
m	meter
MARPOL	International Convention for the Prevention of Pollution from Ships
MEPC	Marine Environment Protection Committee
MBM	Market-based Mechanism
mt	million metric tons
N_2O	nitrous oxide

ppb	part per billion
ppm	parts per million
SEEMP	Ship Energy Efficiency Management Plan
t	metric ton
TEU	Twenty-foot Equivalent Unit
UNFCCC	United Nations Framework Convention on Climate Change

Chapter I

Reduction of GHG Emissions from Ships

1.1 Climate change

Human activities, in particular the rising fossil fuel combustion, have directly emitted growing amounts of greenhouse gases (GHG) into the Earth's atmosphere. A cumulative rise of anthropogenic GHG such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) has led to a rise in the Earth's atmosphere of the heat from the sun that would in principle be rebounded back into space. The increase of heat in the Earth's atmosphere has changed the natural climate variability, resulting in climate change.

The direct impacts of climate change on the Earth can be summarized as follows:

- increases in the average global temperature (global warming),
- changes in cloud cover and precipitation particularly over land,
- melting of ice caps and glaciers and reduced snow cover, and
- increases in ocean temperatures and ocean acidity.

Further, it is well recognized that the major threats caused by the global warming have had severe impacts on human sustainable survival and natural systems, including:

- the rise of the sea mean level,
- the biodiversity losses,
- more frequent and extreme weather events,
- the creation of new diseases,
- the famine aggravation, and
- the losses of traditional lifestyles.

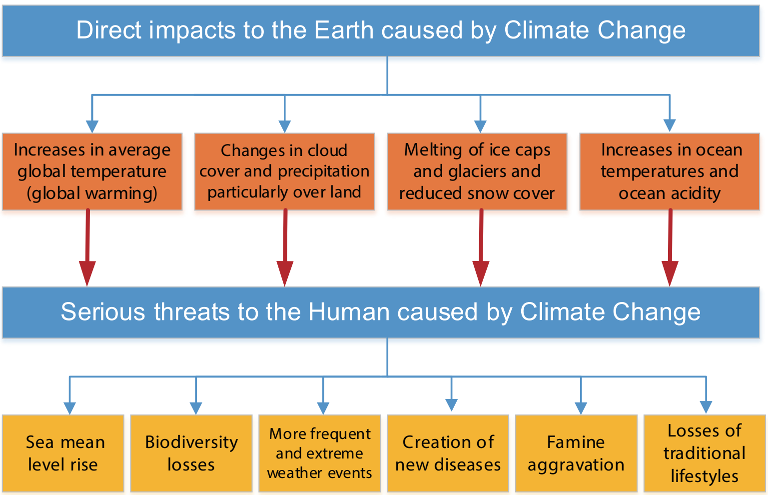


Figure 1-1 Direct impacts and threats to Human caused by climate change

1.2 Global mission in controlling GHG emissions

The study conducted by the Intergovernmental Panel on Climate Change

(IPCC)[1] shows that over the last 160 years, atmospheric concentrations of CO_2, CH_4 and N_2O have increased from a pre-industrial value to 100 parts per million (ppm), 1,000 parts per billion (ppb) and 60ppb, respectively (see Figure 1-2), and globally the averaged surface temperature has a rise of 0.85 [0.65 to 1.06] °C from 1880 to 2012 (see Figure 1-3).

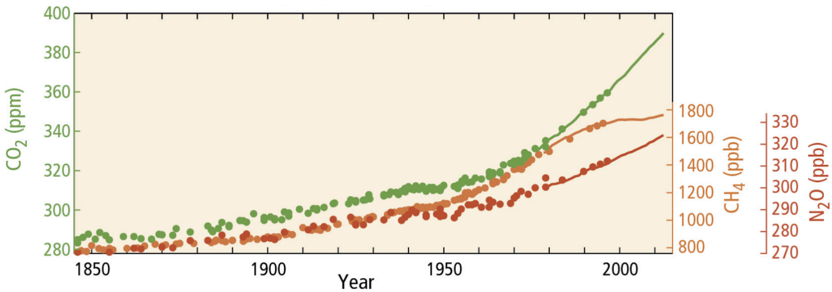


Figure 1-2 Change of global GHG average concentration[2]

In addition, it is projected based upon four global mitigation scenarios (Representative Concentration Pathways)[3] that the increase of the global mean surface temperature relative to 1986-2005 range from a minimum of 0.3°C to as much as 4.8°C rise.

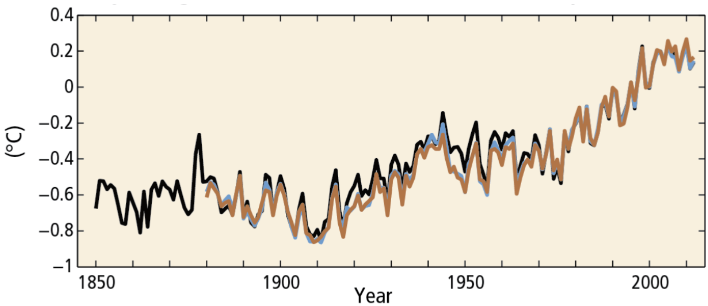


Figure 1-3 Change of global average temperature[4]

Limiting global warming would require all countries and sectors to take coordi-

1 IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

2 Ibid.

3 Ibid.

4 Ibid.

nated actions for the substantial and sustained reductions in the anthropogenic GHG emissions. In this regard, the United Nations Framework Convention on Climate Change (UNFCCC) has been internationally adopted in 1992, which set a goal to achieve stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

Then in 1997, the Kyoto Protocol to UNFCCC has set for the first time binding emissions targets for developed countries, with a view to reducing their overall GHG emissions by 5.0% within 2008-2012 as compared to 1990. In 2012 this requirement was extended until 2020 by the Doha Amendment.

Further, the Paris Agreement to UNFCCC which was adopted in 2015 has reached a global target to maintain the average global temperature rise this century well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C.

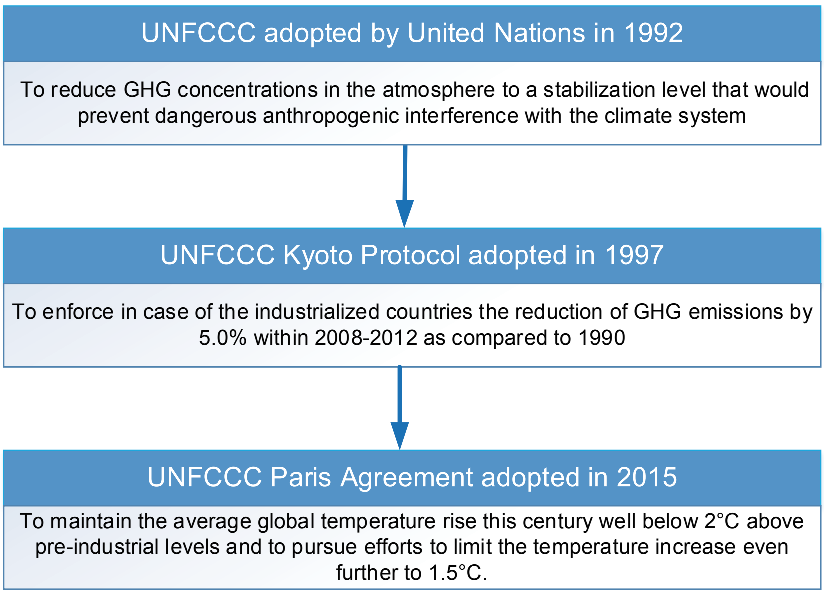


Figure 1-4 Global mission in controlling GHG emissions

1.3 GHG emissions from international shipping sector

International shipping carries over 80% of all traded goods by volume and over 70% by value. About more than 50,000 merchant ships registered in over 150 nations are trading internationally. According to the Third IMO GHG Study 2014[5], international shipping has emitted 866 million tonnes of GHG (in CO_2 equivalent) per year on average between 2007 and 2012 which represented approximately 2.4% of global anthropogenic GHG emissions, and emitted 846 million tonnes of CO_2 emissions per year on average between 2007 and 2012, accounting for about 2.6% of global CO_2 emissions per year on average on the same period. Moreover, despite the amelioration through the technological and operational measures, the future CO_2 emissions from the international shipping sector are projected to rise by between 50% and 250% over the period 2012-2050 based on the business-as-usual (BAU) scenario that assumes a tripling in world trade.

Table 1-1 GHG and CO_2 emissions of international shipping sector from 2007 to 2012 (mt)[6]

Year	GHG	% of global	CO_2	% of global
2007	903	2.6%	885	2.8%
2008	940	2.6%	921	2.9%
2009	873	2.5%	855	2.7%
2010	790	2.1%	771	2.3%
2011	871	2.3%	850	2.4%
2012	816	2.1%	796	2.2%
Average	866	2.4%	846	2.6%

Consequently, it is indispensable that the international shipping industry shall take necessary actions to effectively limit and reduce the GHG emissions from

5 IMO GHG Study, 2014.
6 Ibid.

ships in order to help achieve the goal in controlling the rise of global surface temperature which is laid down in the Paris Agreement to UNFCCC.

1.4 Control of GHG emissions from ships

1.4.1 Leading role of IMO in limiting GHG emissions from ships

The International Maritime Organization (IMO) is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships. In September 1997, an international conference of parties to the International Convention for the Prevention of Pollution from Ships (MARPOL Convention), which adopted the Protocol of 1997 to amend the MARPOL Convention (MARPOL Annex VI), also adopted Conference resolution 8 on CO_2 emissions from ships. This resolution invited the Marine Environment Protection Committee (MEPC) to consider what CO_2 reduction strategies might be feasible in light of the relationship between CO_2 and other atmospheric and marine pollutants. The resolution also invited IMO, in cooperation with the UNFCCC, to undertake a study[7] of CO_2 emissions from ships for the purpose of determining the amount and relative percentage of CO_2 emissions from ships as part of the global inventory of CO_2 emissions.

Kyoto Protocol to UNFCCC calls upon that the parties included in its Annex I shall pursue limitation or reduction of emissions of GHG from marine bunker fuels working through the IMO. Even though the Paris Agreement neither explicitly mentions the international shipping industry in the global GHG emissions reduction targets nor specifically mentions that IMO should be acting as a body setting the international measures to restrict GHG emissions from the international shipping sector, the work regarding international shipping GHG emissions reductions is put, like in the Kyoto Protocol, on the shoulder of IMO in light of the fact that the leading role of IMO in limiting GHG emissions from international shipping industry has been well acknowledged, with its regular submission of reports on this issue, to the UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA).

7 Study of Greenhouse Gas Emissions from Ships, IMO, 2000.

1.4.2 Two principles of reducing GHG emissions from ships

Since almost all merchant ships are propelled by fossil-fuel-powered marine diesels, in principle, there are only two principles in limiting or reducing GHG emissions from ships:

- using less fossil fuels (also called the uptake of energy efficiency), and
- using alternative type of energy.

1.4.3 Three types of measures for reducing GHG emissions from ships

Guided by these two principles and considering the first IMO Study on GHG emissions from ships, in December 2003, the IMO Assembly adopted the resolution A.963(23) on IMO Policies and Practices related to the Reduction of Greenhouse Gas Emissions from Ships, which urged the IMO MEPC to identify and develop the mechanisms needed to achieve the limitation or reduction of GHG emissions from international shipping. There are mainly three types of measures to reduce GHG emissions from ships:

- technology-based measures,
- operation-based measures, and
- market-based measures.

(1) Technology-based measures

The most direct and efficient measure to limit or reduce GHG emissions from international shipping sector is naturally through the advanced technologies to design and build greener ships whose energy efficiency can be greatly promoted and GHG emissions be reduced accordingly. In order to encourage ship designers and builders to reduce CO_2 emissions by freely using the most cost-efficient solutions as well as to stimulate continual technological innovation and development influencing the energy efficiency of a ship, the Energy

Efficiency Design Index (EEDI), a new index reflecting the ship's design energy efficiency, has been developed and established by IMO.

In July 2011, IMO adopted mandatory measures to improve the energy efficiency of international shipping through resolution MEPC.203(62), representing the first-ever global mandatory energy efficiency standard for the international shipping sector, the first legally binding instrument adopted since the Kyoto Protocol to UNFCCC that addresses GHG emissions and the first global mandatory GHG-reduction regime for an international shipping sector.

The amendments adopted by resolution MEPC.203(62) added a new Chapter 4 entitled “Regulations on energy efficiency for ships” to MARPOL Annex VI. This technical requirement applicable to new ships of 400 Gross Tonnage (GT) and above is known as EEDI, which sets a minimum energy efficiency level for the work undertaken for different ship types and sizes, see Annex 1. These mandatory requirements entered into force on 1 January 2013.

EEDI is a non-prescriptive, performance-based mechanism that allows ship designers and builders to freely choose and use any technology for the uptake of a new individual ship’s energy efficiency as long as the attained energy efficiency level is in compliance with the regulations. EEDI is a quantified measure representing the amount of CO_2 generated by a ship while doing one tonne-mile of transport work. EEDI is able to be calculated for each newly built ship using a complex formula consisting of a number of factors and coefficients, such as the ship’s deadweight, emissions and speed, and more technical parameters, to index the impact on environment from shipping vs the benefit to society from shipping. Lower EEDI figure means lower impact on environment from shipping and higher the benefit to society from shipping.

$$\text{EEDI} = \frac{\text{impact on environment from shipping}}{\text{benefit to society from shipping}}$$

$$= \frac{\text{amount of } CO_2 \text{ emissions from ships}}{\text{ship's capacity} \times \text{ship's reference speed}}$$

Furthermore, EEDI requirements increase over time through successive phases with more and more stringent reduction factors, and that they are regularly reviewed to take into account the technological developments.

To date, EEDI requirements of 12 different types of ships are provided by regulations 20 and 21 of MARPOL Annex VI and are specified by various IMO Guidelines, e.g. the 2018 Guidelines on the method of calculation of the attained EEDI for new ships (Resolution MEPC.308(73)).

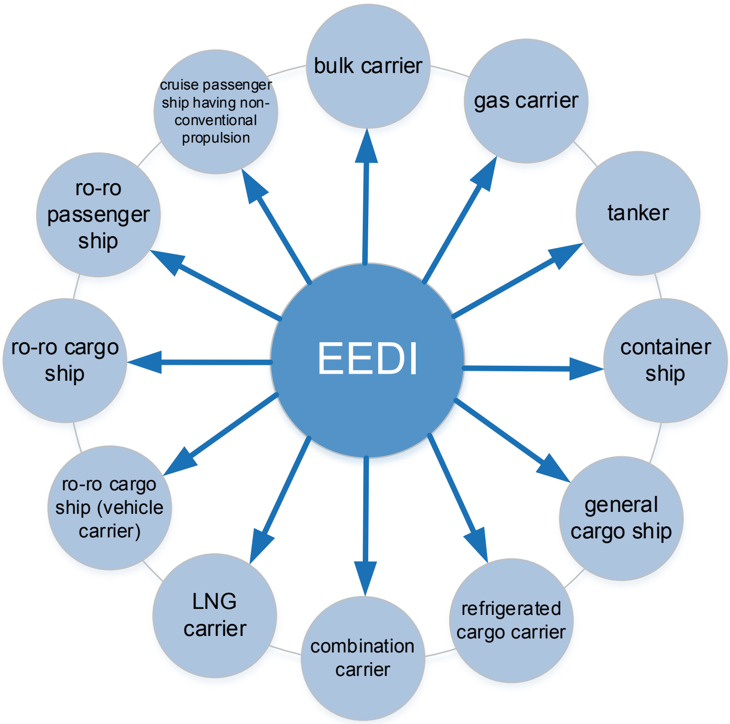


Figure 1-5 Ship types that EEDI has been regulated

(2) Operation-based measures

The compulsory technology-based requirements of EEDI can only be observed by ship's designers and builders as it is only applicable to new ships.

This measure has optimized the world ship fleet of the future. However, there still needs some measures to limit or reduce the GHG emissions from existing ships. It is well recognized that a variety of efficient operations during ship's sailing time, such as improved voyage planning, weather routing, just-in-time arrival at port, speed optimization, optimized shaft power and optimum trim, can also make a noticeable contribution to improving the ship energy efficiency if ship operators and seafarers adequately implement those operations.

Considering both the necessity of introducing efficient operations that can make an invaluable contribution to reducing global GHG emissions into the shipping industry and the flexibility of allowing ship operators to freely decide what measures to adopt for ensuring the uptake of ship energy efficiency, regulation 22 of MARPOL Annex VI also stipulates the mandatory requirements for all ships of 400 GT and above engaged in international voyages to keep on board a specific Ship Energy Efficiency Monitoring Plan (SEEMP).

SEEMP is to establish a mechanism for ship operators to improve the energy efficiency of existing ships in a cost-effective manner. According to the relevant IMO guidelines[8], SEEMP "provides a possible approach for monitoring ship and fleet efficiency performance over time and some options to be considered when seeking to optimize the performance of the ship." This implies that shipping companies may establish the on-shore and on-board management procedure monitoring ship's energy efficiency performance by using a specific tool, such as the Energy Efficiency Operation Indicator (EEOI) and regularly reviewing new technologies and practices to improve ship's energy efficiency.

Each SEEMP is unique to a specific ship and shall provide an approach to monitoring, evaluating and promoting this ship's energy efficiency. The efficient application of SEEMP is recommended by undertaking a four-stage continuous improvement cycle process: planning, implementation, monitoring, and self-evaluation and improvement.

8 Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP), resolution MEPC.282(70), 2016.

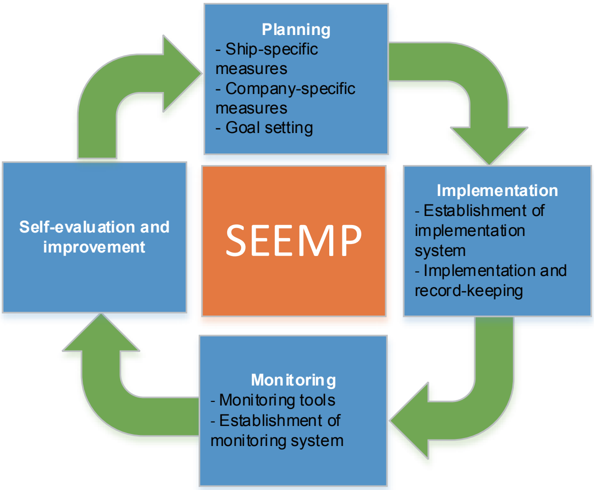


Figure 1-6 SEEMP application process

(3) Market-based measures

Subject to the projected growth of world trade and fleet, market-based mechanisms (MBMs), in addition to the technical and operational measures, could be required to reduce substantially the GHG emissions from international shipping. The aim of an MBM is to put a price on carbon, in order to provide an economic incentive to invest in more efficient technologies or operate ships in a more energy efficient manner (in-sector reductions) and/or to offset emissions generated by ships in other sectors where the reduction of emissions is more economic (out-of-sector reductions).

MBMs have been considered by IMO since 2006. However, due to political divergences among member States and to many remaining technical uncertainties, such as the actual efficiency of such measures to reduce GHG emissions and their possible impacts on the economies of developing countries, these discussions have been suspended so far. The Initial IMO Strategy on reduction of GHG emissions from ships adopted in 2008 identifies the development of "new/innovative emission reduction mechanism(s), possibly including Market-Based Measures, to incentivize GHG emission reduction" as a candidate mid-term measure.

1.5 The Initial IMO Strategy on reduction of GHG emissions from ships

Despite the technical, operational and market-based measures which are applied or have been considered, there still remains in the international shipping sector a question on how much the GHG emissions from ships shall be further reduced in order to ensure that the maritime transport can satisfactorily contribute to the reduction of GHG emissions targets set out by the current global instruments, in particular the Paris Agreement.

In response to this challenge, IMO has adopted in April 2018 an Initial Strategy on reduction of GHG emissions from ships (resolution MEPC.304(72)).

1.5.1 Main content of the Initial Strategy

The Initial Strategy envisages for the first time a reduction in total GHG emissions from international shipping, representing a framework for the future vision for international shipping, the levels of ambition to reduce GHG emissions and guiding principles; and including candidate short-, mid- and long-term further measures with possible timelines and their impacts on States.

The "Vision" set out in the Initial Strategy confirms IMO's commitment to reducing GHG emissions from international shipping and, as a matter of urgency, to phasing them out as soon as possible in this century. Reference is made to the temperature goals of the Paris Agreement in the “Levels of ambition” with the aim to:

- strengthen the energy efficiency design requirements for ships with the percentage improvement for each phase to be determined for each ship type, as appropriate;

- reduce CO_2 emissions per transport work, as an average across international shipping, by at least 40% by 2030, pursuing efforts towards

70% by 2050, compared to 2008; and

- peak GHG emissions from international shipping as soon as possible and to reduce the total annual GHG emissions by at least 50% by 2050 compared to 2008 whilst pursuing efforts towards phasing them out as called for in the Vision as a point on a pathway of CO_2 emissions reduction consistent with the Paris Agreement temperature goals.

In the Initial Strategy, 13 types of candidate short-term measures such as establishment of an Existing Fleet Improvement Programme, 5 types of candidate mid-term measures such as development of a feedback mechanism to enable lessons learned on implementation of measures to be collated and shared through a possible information exchange on best practice, and 2 types of candidate long-term measures are listed, respectively.

As outlined in the Initial Strategy, the impacts on States of a measure should be assessed and taken into account as appropriate before adoption of the measure. In May 2019, MEPC 74 approved the MEPC.1/Circ.885 on Procedure for assessing impacts on States of candidate measures for reduction of GHG emissions from ships. The procedure identifies up to four steps (from an initial to a comprehensive impact assessment) in order to facilitate the best possible anticipation of the potential impacts of candidate measures before adoption.

1.5.2 Key stages based on the three-step approach for the adoption of a Revised Strategy in 2023

To consider further measures to enhance the energy efficiency of ships, a three-step approach was agreed by IMO in 2015 and included in the Initial Strategy:

- step 1: Data collection (2019-2021),
- step 2: Data analysis (2020-2021), and

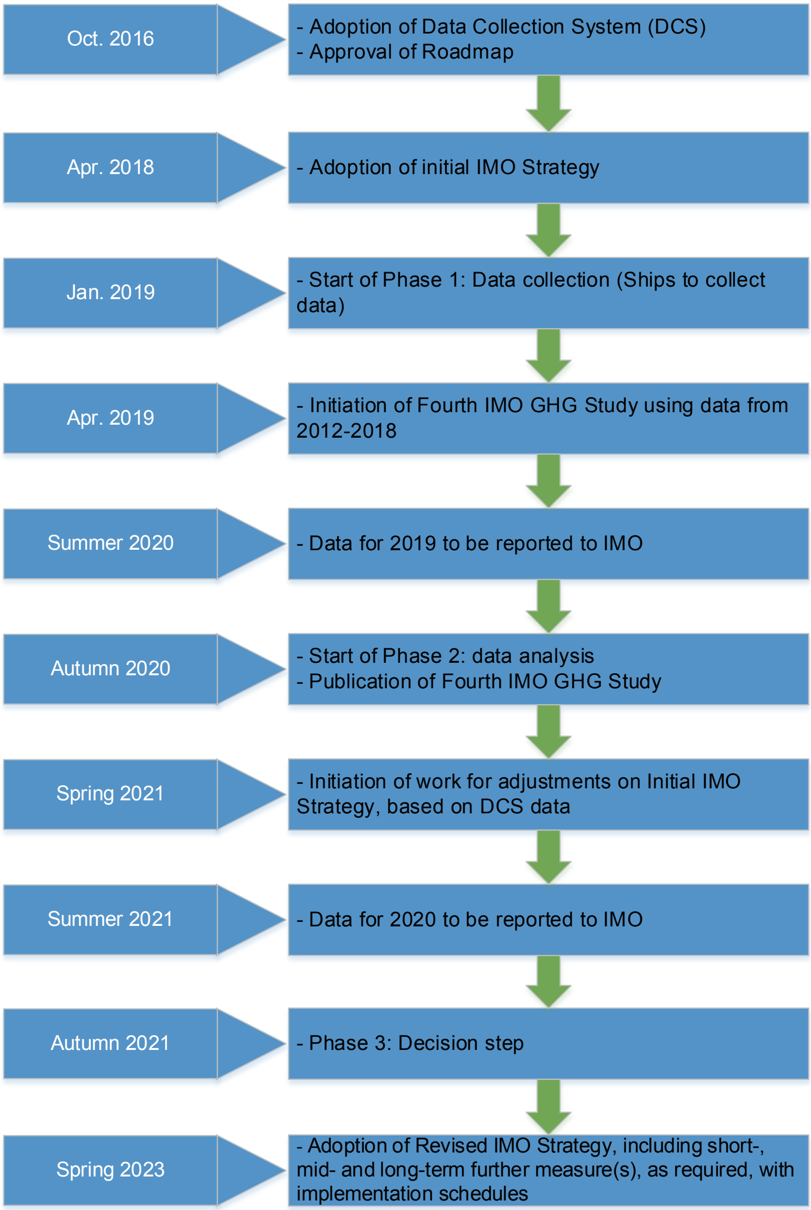


Figure 1-7 Roadmap for developing a comprehensive IMO strategy on reduction of GHG emissions from ships

- step 3: Decision step (2022-2023).

The data collection step involves the collection and reporting of data on ship fuel oil consumption. The data analysis conducted in 2020-2021 will be used to adjust and revise the Initial Strategy in 2023. Further data collection and analysis in the following years will contribute to the decision-making process in the implementation of the Revised Strategy. Figure 1-7 shows the roadmap for developing a comprehensive IMO strategy on reduction of GHG emissions from ships.

1.6 Overview of the international regulatory framework for reducing GHG emissions from ships

The holistic structure of international regulatory regime on mitigating GHG emissions from ships from top to down is comprised by six levels: global target, IMO strategic direction, initial IMO strategy, MARPOL Convention, three specific measures and supportive activities, see Figure 1-8.

IMO has embarked on a strategic direction related to the response to the climate change to demonstrate its responsibility in addressing the global target set in the Paris Agreement. The adopted Initial IMO strategy on reduction of GHG emissions from ships represents a guiding framework for the future vision of the international shipping sector to reduce GHG emissions from ships, which will be mainly achieved through the effective implementation of amendments to the Annex VI of MARPOL Convention and other relevant instruments developed by IMO. Two out of three specific measures, technology-based and operation-based, are already compulsorily implemented as required by MARPOL Convention while the MBMs have been considered. The additional activities including IMO 4th GHG Study, Model Course, technical cooperation and capacity building and a great deal of relevant technical guidelines provide excellent support in developing and implementing the international regulations on GHG emissions reduction from ships. The overall methodology to bridge Initial IMO strategy on reduction of GHG emissions from ships and supportive actions is guided under a three-step approach and the roadmap for developing a strategy on reduction of GHG emissions from ships.

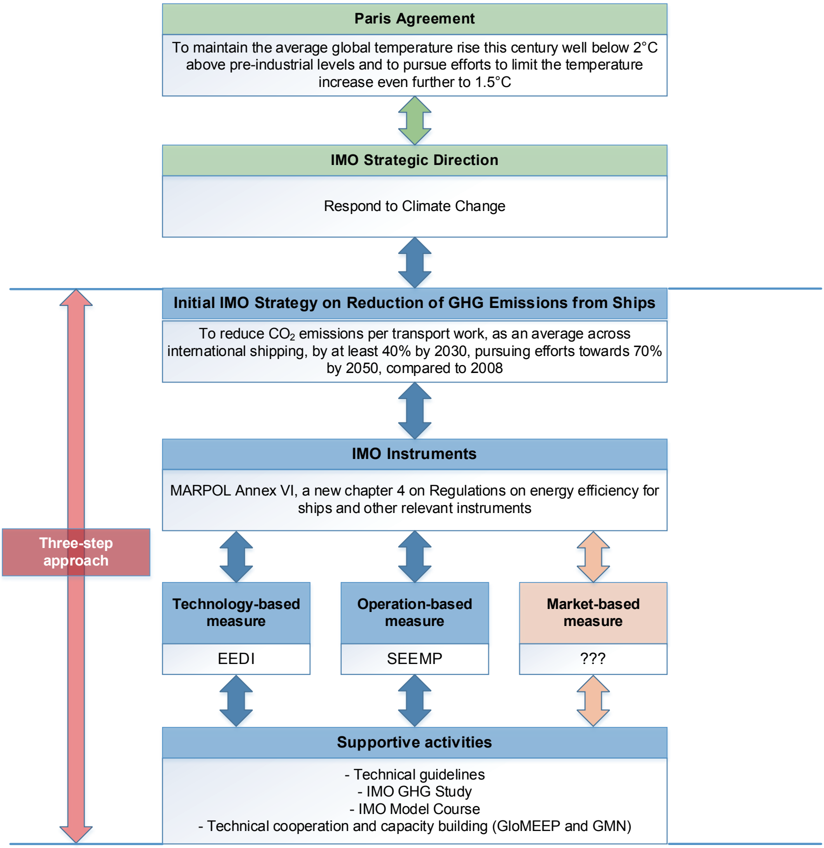


Figure 1-8 International regulatory framework for reducing GHG emissions form ships

As of December 2018, a total of 25 regulations related to the reduction of GHG emissions from ships have been published, as listed in Annex 2.

Chapter II

Theory of Ship Trim Optimization

2.1 Ship's trim

Ship's draft is the vertical distance from ship bottom to water plane. According to different parts of a ship, the draft can consist of six sides: fore draft of port-side, fore draft of starboard side, mid-draft of portside, mid-draft of starboard side, aft draft of portside, aft draft of starboard side.

Ship's trim refers to the difference between the fore draft (the average of fore drafts of portside and starboard side) and the aft draft (the average of aft drafts of portside and starboard side), which is an important indicator representing ship floating state.

When the fore draft is greater than the aft draft, it is called trimmed by bow; when the fore draft is smaller than the aft draft, it is called trimmed by stern; when the fore draft is the same as the aft draft, it is called trimmed on even keel.

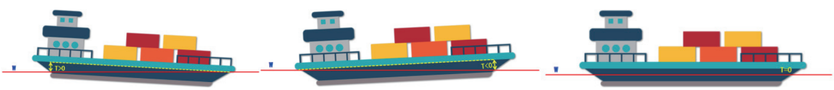


Figure2-1 Three representative states of ship's trim (by bow, by stern and on even keel)

Ship's draft will directly affect the underwater penetration of the propeller and rudder blades, and will also affect log speed, maneuverability and seakeeping performance. In practice, when ships sail in port waters and shallow channels, in order to reach the maximum cargo loading capacity and meet the port requirements, ships are normally adjusted to trim on the even keel. Taking into account the speed performance, the propulsion efficiency, the rudder efficiency and the maneuvering flexibility, a certain trim by stern is usually used when a ship is sailing at sea.

2.2 Relationship between ship's trim and water resistance

The greater water resistance, the greater power, and the higher the fuel consumption. According to the principle of hydrodynamics, the ship resistance is related to the displacement (draft), speed and trim if the external environment is not taken into account.

Ship's water resistance can be divided into frictional resistance, wave-making resistance and shape resistance. These three kinds are all related to factors of the underwater geometry of hull, the length of the waterline, the position of the buoyancy center, and the distribution of the bow and stern flow field. The change of the trim will cause a change in the above factors, which leads to a corresponding change in the ship resistance.

Ship water resistance
- Frictional Resistance
  ---related with the wetted surface, the waterline length and the ship speed
- Wave-making Resistance
  ---related with the bow shape and the ship speed
- Shape Resistance
  --- related with the stern shape and the ship speed

Figure 2-2 Ship's water resistance

2.3 Ship's optimum trim

2.3.1 Definition of optimum trim

When the displacement (draft) and speed are determined, ship water resistance is only related to its trim, if the external environment is not taken into account. There is a trim which minimizes the ship resistance, the main engine power and the fuel consumption at the same speed. This theoretical trim is called the optimum trim for this ship. Figure 2-3 shows the optimum trim for a ship with different displacements at the speed of 15kn.

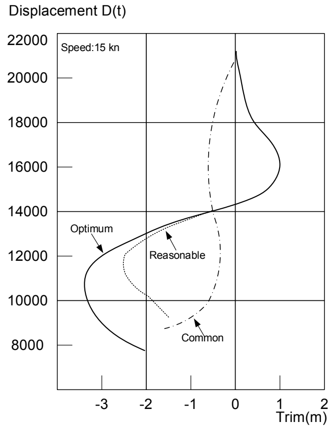


Figure 2-3 Ship's Optimum Trim[9]

2.3.2 Category of optimum trim

The optimum trim operation refers to the operation of keeping the ship in optimum trim state when ship sailing at sea. It can be divided into static optimal operation and dynamic optimal operation. Static optimal operation means that the adjustment of optimum trim is completed at the stages when the ship is still, such as cargo handling and before a ship's departure. Dynamic optimal operation refers to the real-time or intermittent adjustment when the ship is moving in order to keep the ship in the optimum trim state during the entire voyage.

2.3.3 Advantages of using trim optimization operation

Improving ship energy efficiency by using trim optimization has the following advantages:

- Strong applicability. There is no need to change ship structure and install additional devices;

9 Lin Hongbo, Zhu Guangyuan. Optimum Trim, Energy - Saving and Safety of Navigation [J]. Navigation of China,1985,(02):11-23.

- Easy operation. It can be easily achieved by adjusting the fore draft and aft draft manually or automatically;
- Little influence. It neither reduces the ship cargo loading capacity and speed nor compromises the ship's safety of machinery and cargo; and
- Remarkable effect. It can save 2%-6% energy for ships.

2.3.4 Disadvantages of using trim optimization operation

When using trim optimization operation, the optimum trim may cause excessive trim by the stern or excessive trim by the bow.

(1) Excessive trim by stern will cause:

- easily damaging the bottom plate of bow by waves;
- enlarged bridge blind area;
- ship maneuverability deterioration; and
- ship speed ability deterioration.

(2) Excessive trim by bow will cause:

- easy shipping of water on fore deck;
- easy exposure to the water surface of propeller blades and rudder plates, resulting in propeller driving or racing as ship is pitching and heaving;
- ship maneuverability deterioration; and
- ship speed ability deterioration.

2.4 Method of determining ship's optimum trim

There are four main methods to determine ship's optimum trim: Computational Fluid Dynamics (CFD), tank testing, sea trials and machine learning method.

2.4.1 Computational Fluid Dynamics

CFD methods can be used by establishing a numerical model of a ship, calculating the ship water resistance under different trims, and finally obtaining the optimum trim at which the water resistance is minimal. The calculation results can be displayed by cloud and vector maps in a vivid and intuitive manner.

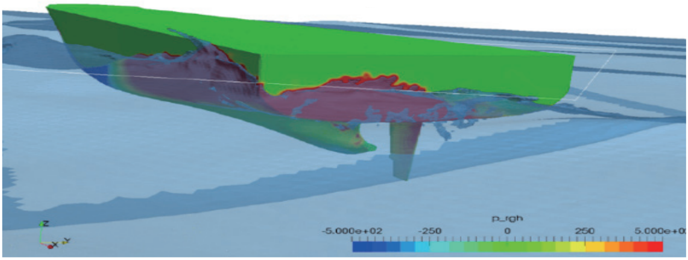


Figure 2-4 Computational Fluid Dynamics (CFD) method

2.4.2 Tank testing

Tank testing is a method where the speed of a ship model is accurately controlled in still water by towing the ship model, and then the water resistance, hull sinking value and trim at different speeds are recorded. Thus, the lowest value of trim is determined when the water resistance of the ship model is the smallest.

Figure 2-5 Tank testing method

2.4.3 Sea trial

A sea trial is used to collect data about ship's power, trim and fuel consumption under 7^3 working conditions (7 speeds, 7 drafts and 7 trims) at least through the automatic ship-borne data acquisition system in special sea test waters. Thus, based on these real data collected, the optimum trim of ships is able to be determined.

Figure 2-6 Sea trial method

2.4.4 Machine learning method

Machine learning is an intelligent data analysis method, which can automatically analyze the characteristics of the model. By using an iterative learning algorithm for massive amounts of data, the computer can discover hidden association of data. The relationship between trim, speed and ship resistance can be obtained if the machine learning method is used to continuously mine and update the collected ship navigation basic data (big data). Thus, the corresponding optimum trim when the ship resistance is the smallest can be determined.

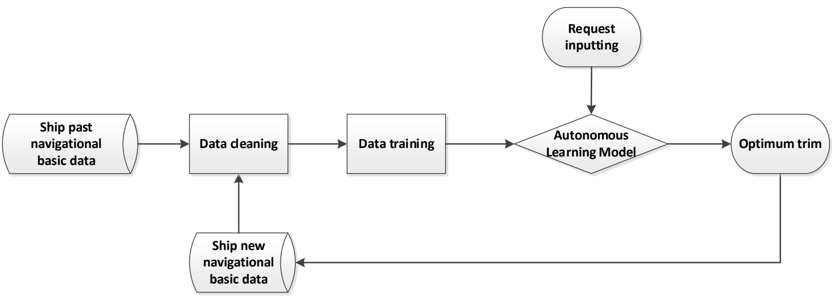


Figure 2-7 Machine learning method

2.4.5 Advantages of ship trim optimization by using machine learning method

Machine learning method is an intelligent data analysis method, which can automatically analyze the characteristics of the model. By using the iterative learning algorithm, the collected ship navigational basic data (big data) can be continuously mined and updated, and self-learning and self-correction can be carried out with increasing data samples to reduce the error between the predicted value and the real value. The intrinsic relation of these data can be excavated by machine learning method, and the relationship between the factors such as ship's sailing speed, trim, draft and fuel consumption can be obtained. Thus, the trim corresponding to the minimum fuel consumption of a ship at a certain speed and draft can be determined. Using machine learning method to optimize trim for the purpose of saving fuel consumption has the key advantages of more accuracy, lower cost and easier operation as long as a sufficient amount of ship past navigational data is available that is of a sufficient quality. It also has the self-learning and advanced function of adapting to the ship's voyage.

Chapter III Operation of Ship Trim Optimization based on Machine Learning Method

3.1 Basic procedure

There are two steps of determining the ship optimum trim through using a machine learning method based on big data analysis:

- Acquire the past ship navigational basic data and set up initial model of the ship trim optimization; and

- Collect continuously the ship navigational basic data, synchronize data iteration, and improve the ship trim optimization model.

3.2 Data preparation

3.2.1 Types of ship navigational basic data

To obtain the ship optimum trim through machine learning method based on big data analysis, the ship navigational basic data at least need to be acquired as follows: date, time, navigational status, mean draft (or fore draft, aft draft), speed, fuel consumption of main engine, and trim.

3.2.2 Method of acquiring past navigational basic data of the ship

The following methods of acquiring past navigational basic data of the ship to determine the ship optimum trim through machine learning methods based on big data analysis can be utilized:

(1) Electronic data recording system

Provided the ship has already installed this system, various types of sensors in it can be used in good condition to automatically and directly record the basic data of the ship's navigation over a long period of time.

(2) Daily noon report

If the ship is not equipped with an electronic data recording system, it is suggested to acquire the ship past navigational basic data from its noon reports.

(3) Data from sister ships

If the noon reports are not available, it is a good option to acquire the ship past navigational basic data from its sister ship's electronic data recording system or noon reports.

(4) Report of sea trial

The last option for acquiring the ship past navigational basic data provided that relevant data from its sister ship is unavailable is to check the data from its report of sea trail.

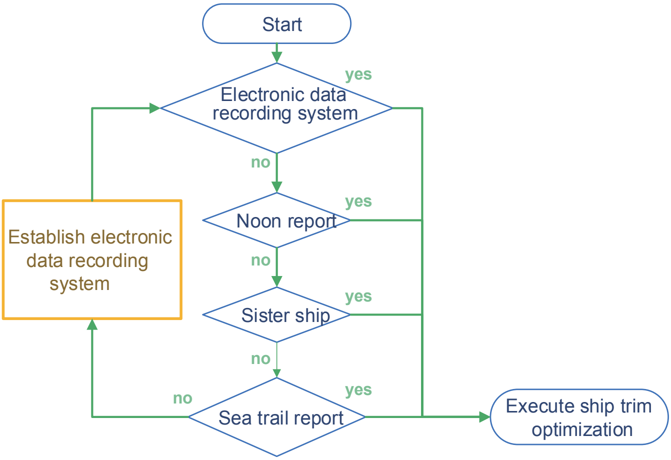


Figure 3-1 Methods for acquiring ship past navigational data and their priorities

3.2.3 Ship navigational data acquisition through short sea trial

If none of the above data can be obtained, or the noon reports are not detailed enough or lacking in quality. This can be due to the fact that the noon reports are only recorded once a day and it can be rare to have noon reports that would have enough detailed information for fore and aft draft and related fuel consumption at different trims.

A solution to this is to carry out a short sea trial when the ship is sailing at sea. Recording data at the same time when the weather conditions would be approximately the same would also be advantageous. During the sea trial, the ship should keep a certain trim and navigate at a certain speed for a certain distance. After the navigation is stable, the crew will record the weather, speed, trim, draft and the corresponding fuel consumption. The fuel consumptions corresponding to different speeds, drafts and trims can be obtained through several sea trials, and the detailed navigation data of the ship can be obtained as training datasets for the trim optimization based on the machine learning method.

3.2.4 Additional notes

It is strongly recommended that the above-mentioned methods should be comprehensively considered as practicable as possible for the sake of acquiring the past navigational basic data of the ship in a prompt and accurate manner.

Also, it is recommended that the electronic data recording system using sensors to automatically record the navigational basic data of the ship should be appropriately established for the ships which have yet to install such systems on board.

3.3 System establishment

3.3.1 System requirements

(1) Requirements of training data set

There is a minimum requirement for the amount of training data in the system of ship trim optimization by machine learning method based on big data analysis. The system can provide reliable conclusions that fit the objective rule only if the training data reaches an effective amount and is continually updated. The magnitude of training data is directly related to the adopted algorithm, which can be tested and validated during the system development process.

(2) Requirements of equipment connection

Either the static or dynamic trim optimization system needs to be connected with the navigational basic database of the ship, in which the data is collected by sensors connected to the network. The collected data can be sent to the onshore management department through the satellite communication network to realize the function of data backup and onshore decision-making support. As far as the dynamic trim optimization system is concerned, it should be connected with the tank control valve to achieve automatic optimization control of the trim.

3.3.2 System functions

Based on the ship navigational basic data, the corresponding relation between trim and various navigational data via the machine learning method can effectively be figured out and thus provide the ship optimum trim range.

The user interface of a ship trim optimization system based on machine learning method is normally comprised by three areas: the parameters input area, value display area and visual area.

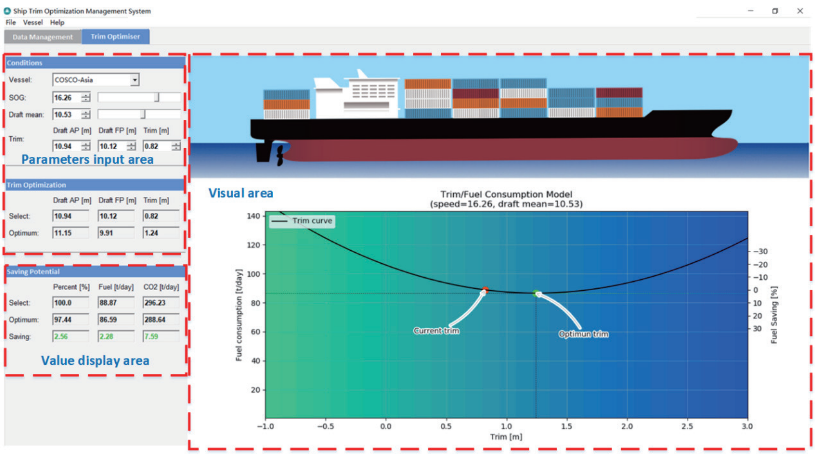


Figure 3-2 Interface of a ship trim optimization system

The parameters input area is designed to automatically obtain or manually input data such as fore draft, aft draft, trim, speed. The value display area can simultaneously show the percentage of fuel saved based on the data input in the parameters area. The visual area shows the corresponding relationship between fuel consumption and trim. The lowest point of the curve is the fuel consumption corresponding to the optimum trim.

3.4 Case study

3.4.1 Containership

(1) Data acquisition

This containership is engaged in international voyages with the design speed of 25kn and the loading capacity up to 10,000 TEUs. The past navigational basic data of the ship from September 14, 2017 to September 15, 2018 was collected by using the electronic data recording system equipped on the ship. After the data cleaning, a total of 22,972 valid sets of data were obtained. As shown in Table 3-1, each data includes date and time, navigational status, speed, fuel consumption, fuel type, draft mean, trim.

Table 3-1 Sample of past navigational basic data of containership

No.	Date and time	Status	Speed (kt)	Main engine		Draft mean (m)	Trim (m)
				Fuel cons.	Fuel type		
1	2017/9/14 11:45	Underway	11.0	0.38	HFO	9.7	0.77
2	2017/9/14 13:00	Underway	12.0	0.33	HFO	9.6	0.77
3	2017/9/14 13:15	Underway	12.0	0.31	HFO	9.6	0.77
4	2017/9/14 13:30	Underway	12.0	0.31	HFO	9.6	0.77
5	2017/9/14 13:45	Underway	12.0	0.31	HFO	9.6	0.78
6	2017/9/14 14:00	Underway	12.1	0.33	HFO	9.6	0.77
7	2017/9/14 14:15	Underway	12.1	0.31	HFO	9.6	0.77
8	2017/9/14 14:30	Underway	12.1	0.29	HFO	9.6	0.77
9	2017/9/14 14:45	Underway	12.0	0.28	HFO	9.6	0.77
10	2017/9/14 15:00	Underway	11.8	0.28	HFO	9.6	0.77
11	2017/9/14 15:15	Underway	11.7	0.33	HFO	9.6	0.79
12	2017/9/14 15:30	Underway	11.8	0.34	HFO	9.6	0.79
13	2017/9/14 15:45	Underway	11.9	0.34	HFO	9.6	0.76
14	2017/9/14 16:00	Underway	12.1	0.33	HFO	9.6	0.77
15	2017/9/14 16:15	Underway	12.1	0.34	HFO	9.6	0.77
16	2017/9/14 16:30	Underway	12.1	0.37	HFO	9.6	0.76
17	2017/9/14 16:45	Underway	12.3	0.37	HFO	9.6	0.78
18	2017/9/14 17:00	Underway	12.5	0.37	HFO	9.6	0.80
19	2017/9/14 17:15	Underway	12.5	0.37	HFO	9.5	0.82
20	2017/9/14 17:30	Underway	12.4	0.38	HFO	9.5	0.80

(2) Data analysis

Due to uncertain reasons, some raw data fields were not completely collected from the real ships, i.e. there were nulls existing in some data fields. On the contrary, some raw data were completely same, which indicated that the same data was repeatedly collected. In addition, a small quantity of raw data was classified as outlier because they were obviously against the physical rules and real operations, e.g. the draft was more than 30m or the trim was over 4m. Therefore, the raw data should be cleaned firstly in order to ensure that the data which will be used for further analysis is accurate, consistent and reliable as far as possible.

Based on the data that has been successfully cleaned, the optimum trim of the ship under given draft and speed can be determined by using the appropriate algorithm of the machine learning, as shown in Figure 3-3 (the abscissa indicates trim and the ordinate indicates fuel consumption).

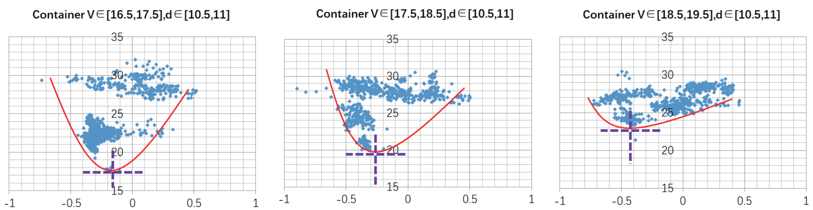


Figure 3-3 Determination of optimum trim for containership

When the draft remains constant, the optimum trims (fore draft minus aft draft) of the containership at three primary speeds are all negative, and the value of the optimum trim increases as the ship speed rises. Therefore, it is beneficial to saving fuel consumption when the ship is sailing trimmed by bow at sea.

Figure 3-4 shows the relation between draft, trim and fuel consumption of the containership at its primary speed of 16.5-17.5 kn (the abscissa indicates the trim, the ordinate indicates the draft, and the blue dots indicate the actual fuel consumption).

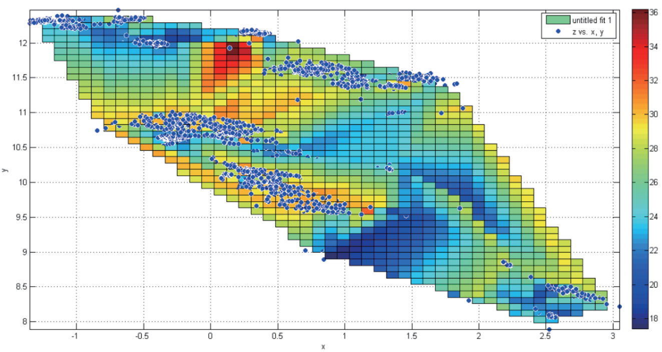


Figure 3-4 Relation between draft, trim and fuel consumption of containership

Therefore, when the container ship is steaming at a speed of 16.5-17.5kn with a draft of 10.5m, the optimum trim is 0.75-0.80m, and the corresponding fuel consumption is about 5.83% less than the actual fuel consumption.

3.4.2 Bulk carrier

(1) Data acquisition

The bulk carrier is engaged in coastal voyages with the design speed of 14kn and gross tonnage of about 38,000. The past navigational basic data of the ship from February 3 to August 30, 2018 was collected from the ship through its noon reports and its sister's noon reports. After data cleaning, a total of 488 valid sets of data were obtained. As shown in Table 3-2, each set of data includes date, navigational status, speed, fuel consumption, fuel type, draft mean, trim.

Table 3-2 Sample of past navigational basic data for bulk carrier

No.	Date	Status	Speed (kt)	Main engine		Draft mean (m)	Trim (m)
				Fuel cons.	Fuel type		
1	2018/2/3	Underway	11.1	18.1	HFO	10.8	0.07
2	2018/2/4	Underway	11.1	9.8	HFO	10.8	0.07
3	2018/2/7	Underway	11.8	16.6	HFO	7.3	1.50
4	2018/2/8	Underway	11.8	2.3	HFO	7.3	1.50
5	2018/2/15	Underway	10.1	12.3	HFO	7.3	1.50
6	2018/2/26	Underway	11.7	7.9	HFO	14.4	0.17
7	2018/2/27	Underway	12.0	31.2	HFO	14.4	0.17
8	2018/2/28	Underway	10.2	31.3	HFO	14.4	0.17
9	2018/3/1	Underway	11.0	26.2	HFO	14.4	0.17
10	2018/3/2	Underway	11.0	22.6	HFO	14.4	0.17
11	2018/3/8	Underway	9.6	12.5	HFO	7.4	1.20
12	2018/3/9	Underway	9.7	27.7	HFO	7.4	1.20
13	2018/3/10	Underway	12.0	29.7	HFO	7.4	1.20
14	2018/3/11	Underway	13.0	28.7	HFO	7.4	1.20
15	2018/3/12	Underway	12.0	12.0	HFO	7.4	1.20
16	2018/3/14	Underway	12.0	13.6	HFO	14.4	0.11
17	2018/3/15	Underway	13.0	30.8	HFO	14.4	0.11
18	2018/3/16	Underway	12.3	29.8	HFO	14.4	0.11
19	2018/3/17	Underway	12.0	30.6	HFO	14.4	0.11
20	2018/3/18	Underway	12.1	26.3	HFO	14.4	0.11

(2) Data analysis

Based on the data that has been successfully cleaned, the optimum trim of the ship under given draft and speed can be determined by using the appropriate algorithm of the machine learning, as shown in Figure 3-5 (the abscissa indicates trim and the ordinate indicates fuel consumption).

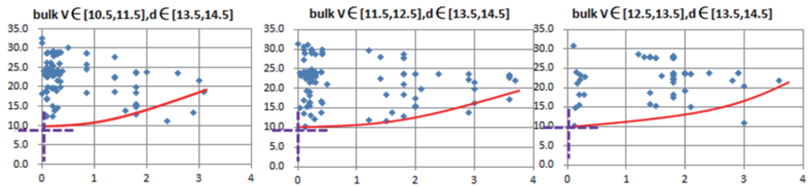


Figure 3-5 Determination of optimum trim for bulk carrier

When the draft remains constant, the optimum trims (fore draft minus aft draft) of the container ship at three primary speeds increases as the ship speed rises. Therefore, it is beneficial to saving fuel consumption when the ship is sailing trimmed by bow at sea.

Figure 3-6 shows the relation between draft, trim and fuel consumption of the container ship at its primary speed of 13.5-14.5kn (the abscissa indicates the trim, the ordinate indicates the draft, and the blue dots indicate the actual fuel consumption).

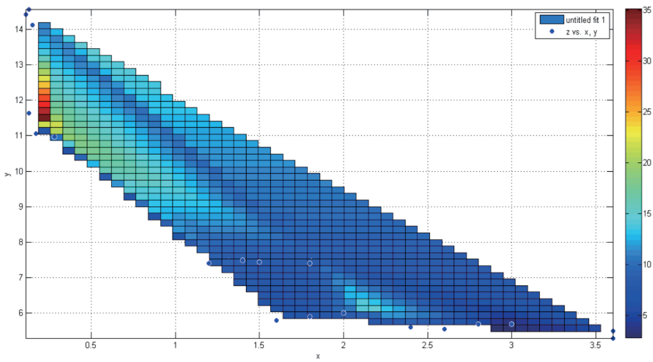


Figure 3-6 Relation between draft, trim and fuel consumption of bulk carrier

Therefore, when the bulk carrier is steaming at a speed of 13.5-14.5kn with a draft of 10.5-11.5m, the optimum trim is 0.00-0.01m, and the corresponding fuel consumption is about 3.77% less than the actual fuel consumption.

3.4.3 Oil tanker

(1) Data acquisition

The oil tanker is engaged in voyages within Asian waters with the design speed of 15kn and gross tonnage of about 60,000. The past navigational basic data of the ship from May 5, 2017 to May 5, 2018 was collected from the ship through its noon reports and its sister's noon reports. After data cleaning, a total of 1,375 valid sets of data were obtained. As shown in Table 3-3, each set of data includes date, navigational status, speed, fuel consumption, fuel type, draft mean, trim.

Table 3-3 Sample of past navigational basic data for oil tanker

No.	Date and time	Status	Speed (kt)	Main engine		Draft mean	Trim
				Fuel cons.	Fuel type		
1	2017/5/19	Underway	9.1	4.4	HFO	11.6	0.6
2	2017/5/20	Underway	12.7	26.6	HFO	11.6	0.6
3	2017/5/21	Underway	12.0	27.0	HFO	12.5	0.6
4	2017/5/22	Underway	10.0	20.2	HFO	12.0	0.8
5	2017/5/26	Underway	9.9	9.7	HFO	11.9	0.9
6	2017/5/27	Underway	19.2	17.5	HFO	12.3	0.1
7	2017/6/17	Underway	9.1	6.5	HFO	12.3	0.1
8	2017/6/19	Underway	12.9	26.2	HFO	12.6	0.1
9	2017/6/20	Underway	11.1	25.6	HFO	12.6	0.5
10	2017/7/13	Underway	13.2	26.9	HFO	12.8	0.1
11	2017/7/14	Underway	13.3	31.8	HFO	12.9	0.4
12	2017/7/15	Underway	12.9	25.5	HFO	11.9	0.1
13	2017/7/16	Underway	7.7	26.7	HFO	11.7	1.0
14	2017/7/18	Underway	20.2	8.0	HFO	11.4	1.0
15	2017/7/19	Underway	2.9	5.5	HFO	11.3	0.1
16	2017/7/20	Underway	12.3	22.2	HFO	12.8	0.8
17	2017/7/21	Underway	11.0	9.1	HFO	11.4	0.3
18	2017/7/30	Underway	9.8	4.5	HFO	12.2	0.6
19	2017/7/31	Underway	7.5	4.1	HFO	11.5	0.8
20	2017/8/1	Underway	12.0	14.7	HFO	11.8	0.8

(2) Data analysis

Based on the data that has been successfully cleaned, the optimum trim of the ship under given draft and speed can be determined by using the appropriate algorithm of the machine learning, as shown in Figure 3-7 (the abscissa indicates trim and the ordinate indicates fuel consumption).

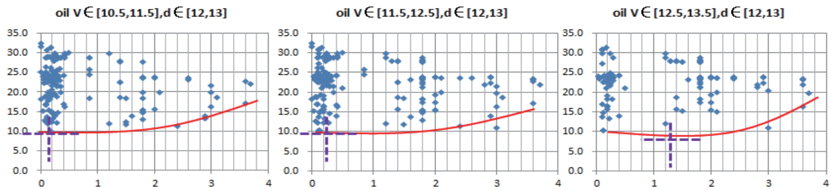


Figure 3-7 Determination of optimum trim for oil tanker

When the draft remains constant, the optimum trims (fore draft minus aft draft) of the oil tanker at three primary speeds increases as the ship speed rises. Therefore, it is beneficial to saving fuel consumption when the ship is sailing trimmed by bow at sea.

Figure 3-8 shows the relation between draft, trim and fuel consumption of the container ship at its primary speed of 11.5-12.5kn (the abscissa indicates the trim, the ordinate indicates the draft, and the blue dots indicate the actual fuel consumption).

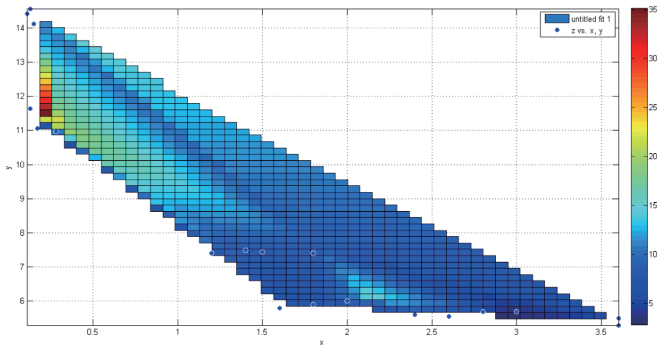


Figure 3-8 Relation between draft, trim and fuel consumption of oil tanker

Therefore, when the oil tanker is steaming at a speed of 11.5-12.5kn with a draft of 12.0-13.0m, the optimum trim is 0.00-1.13m, and the corresponding fuel consumption is about 5.73% less than the actual fuel consumption.

Chapter IV Conclusions and Precautions

4.1 Conclusions

The conclusions related to the ship trim optimization based on the machine learning method can be drawn as follows:

- In theory, there is an optimum trim existing for each ship which enables the ship to suffer the least water resistance and to consume the least fuel provided that its displacement (draft) and speed are determined.

- For a ship, the trim optimization effectiveness that ship is sailing at deep draft is better than that ship is sailing at light draft.

- Trim optimization may produce better effectiveness for a ship with faster design speed, bulb bow and wider stern, especially for big containerships.

- The ship would save more fuel consumption when sailing trimmed by bow at sea.

- The machine learning method based on the big data analysis is a good and reliable approach to conducting the operations of dynamic trim optimization provided that the sufficient ship past navigational basic data is available that is of a sufficient quality.

- Intelligent management for ships is an inevitable trend. Thus, shipping companies should attach great importance to raising the awareness of, as well as on implementing the operations of, collecting and storing the ship navigational basic data as the data is fundamental but invaluable to achieve the ship intelligent management.

- The following methods of acquiring past navigational basic data of the ship to determine the ship optimum trim through machine learning methods based on big data analysis can be utilized: shipborne electronic data recording system, daily noon report, data from sister ships, and report of sea trial. The machine learning method has the self-learning and advanced function with adapting to the ship's voyage.

4.2 Precautions

The following precautions should be specially taken as the ship trim optimization operations based on the machine learning is utilized:

- By no means should the trim optimization operation hinder the ship's safety and pollute the marine environment.

- The ship optimum trim should meet the requirements of the permissible stress and the allowable hull strength.

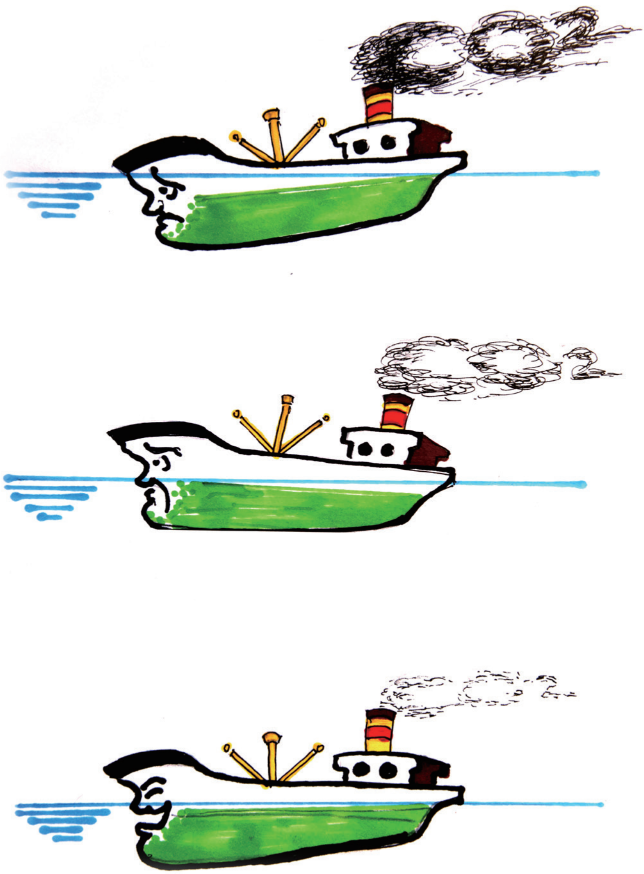
- While the ship optimum trim is against with the ship safety requirements, the trim which is within the safety limits but closest to the optimum trim could be adopted.

- For static trim optimization operations, the application of the optimum trim should also consider the parameters such as varied wind conditions and water densities in the various sea areas that the ship is intended to pass during the entire voyage.

- For container ship, the optimum trim should be considered as the containers and ballast water are handling.

- For oil tanker, the free surface effect of tanks should be considered during the adjustment of optimum trim.

- For bulk carrier during the voyage, cargo movements may cause the shift of ship’s gravity while cargoes which may liquefy may cause new free surface effect.



Chapter V Overview of Ship Trim Optimization System

5.1 Introduction

A demo ship trim optimization software is included in the folder TrimOptimiser of the accompanying USB stick. The basic operating system requirements of running this demo software is at least 32-bit Windows 10.The ***Excel*** file of ***Testdata.xlsx*** which is the tailor-made test data for this demo software can be found in the folder data after double clicking the folder TrimOptimiser . It is suggested for effectively running this demo software to copy the folder TrimOptimiser from USB stick to hard disc of a computer before starting the software.

5.2 Data preparation

The data for successfully running ***TrimOptimiser*** includes 6 data fields, i.e. date and time, ME consumed, speed, draft mean, trim and vessel name. To demonstrate the function of ***TrimOptimiser***, the data can be manually inputted in the ***Excel*** file (see Figure 5-1 a snapshot from the***Testdata.xlsx***). Please note that as inputting the preparation data in the Excel file, the names of 6 data fields, date and time, ME consumed in ton, speed in knot, draft mean in meter, trim in meter, and vessel name are compulsory required and should keep their format same as those shown in the ***Testdata.xlsx***. (It is suggested to fill in the

NULL if a data is not available and input the vessel name once at least.)

Date and time	ME consumed	Speed	Draft mean	Trim	Vessel name
2017/11/24 14:00	110.5	17.4	12.0	0.7	TEST
2017/11/24 14:15	111.1	17.8	11.8	0.9	
2017/11/24 14:30	116.5	18.3	11.7	0.9	
2017/11/24 14:45	116.7	18.3	11.6	1.0	
2017/11/24 15:00	118.1	18.2	11.6	1.0	
2017/11/24 15:15	115.0	18.0	11.6	1.1	
2017/11/24 15:30	117.6	18.1	11.6	1.1	
2017/11/24 15:45	120.7	18.7	11.6	1.0	
2017/11/24 16:00	120.2	18.7	11.6	1.0	
2017/11/24 16:15	116.0	18.2	11.6	1.1	
2017/11/24 16:30	115.5	17.9	11.5	1.2	
2017/11/24 16:45	120.9	18.6	11.5	1.1	
2017/11/24 17:00	121.0	18.7	11.5	1.1	
2017/11/24 17:15	121.2	18.7	11.6	1.1	
2017/11/24 17:30	122.8	18.8	11.5	1.1	
2017/11/24 17:45	124.1	18.8	11.5	1.1	
2017/11/24 18:00	121.0	18.8	11.5	1.1	
2017/11/24 18:15	121.1	18.9	11.5	1.0	
2017/11/24 18:30	121.3	18.9	11.5	1.1	
2017/11/24 18:45	122.8	18.9	11.5	1.1	

Figure 5-1 Data format requirement for *TrimOptimiser*

5.3 Data import

After the completion of data preparation, double click the TrimOptimiser.exe in the folder ***TrimOptimiser*** for running the system. For the first time to launch the system the Tab ***Data Management*** (in blue background) will be automatically activated but the data of all fields in this Tab is blank, see Figure 5-2.

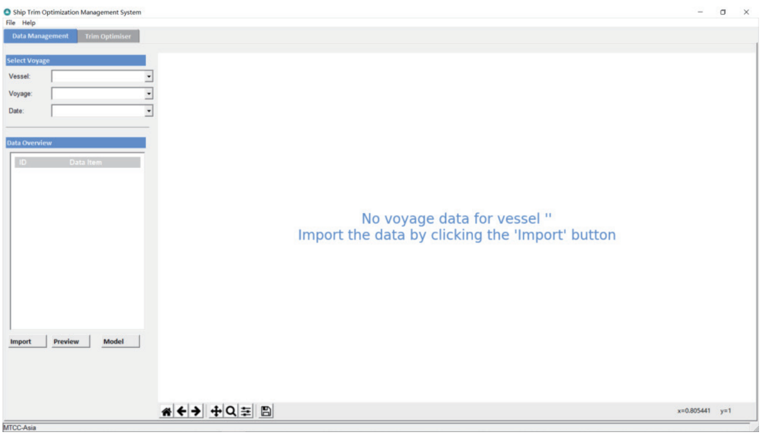


Figure 5-2 Snapshot for initializing the *TrimOptimiser*

Then click the Button Import on the left corner of the Tab ***Data Management*** screen, the ***File Dialog Window*** appears and the data Excel file can be found and selected. After clicking the "***OK***" button in the ***File Dialog Window***, the ***Dialog Window*** indicating "1 of 1 files have been imported!" will be shown (see Figure 5-3), which means that the data in the Excel files selected has been successfully imported.

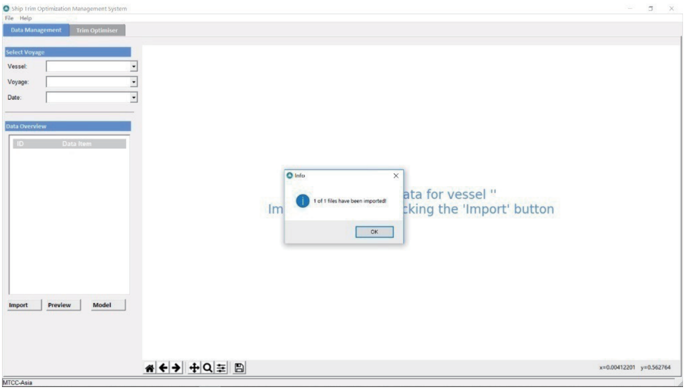


Figure 5-3 *Dialog window* indicating the data has been successfully imported

By clicking the "***OK***" button in the ***Dialog Window***, the data, including vessel name, voyage, date, and line figures representing the relation between date and fuel consumption, speed, draft mean and trim will automatically be shown in the corresponding areas of the ***Data Management Window***, see Figure 5-4.

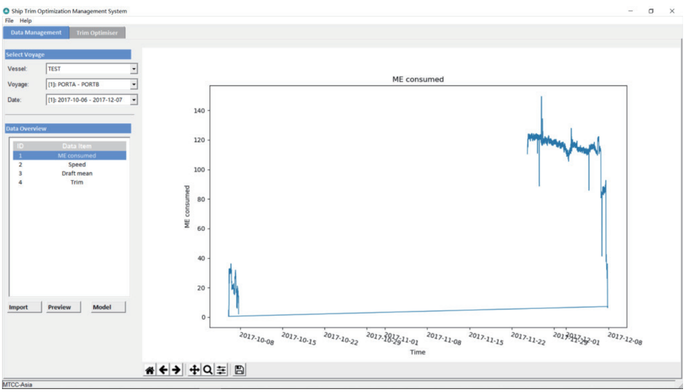


Figure 5-4 Snapshot of *Data Management Window* after data import

5.4 Model review

By clicking the button Model in the ***Data Management Window***, the three-dimensional relation among fuel consumption of main engine, trim and speed at given mean draft can be clearly shown, see Figure 5-5.

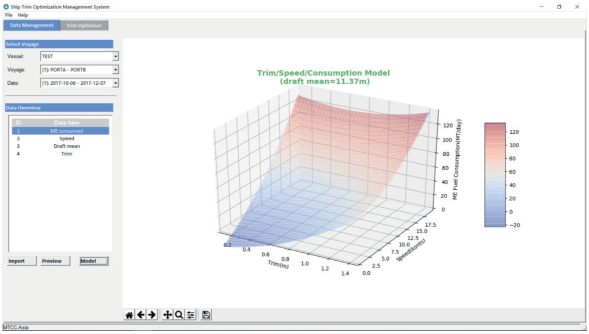


Figure 5-5 Three-dimensional model for ship optimum trim

5.5 Optimum trim determination

By clicking the Tab Trim Optimiser on the right side of the Tab ***Data Management***, the ***Trim Optimiser Window*** can be activated (see Figure 5-6), in which the ship optimum trim and fuel savings can be automatically determined in the format of number and line as the ship speed and drafts change. (The picture of ship type can be correspondingly shown by clicking the ***Vessel*** in the Menu and selecting the corresponding the ship type.)

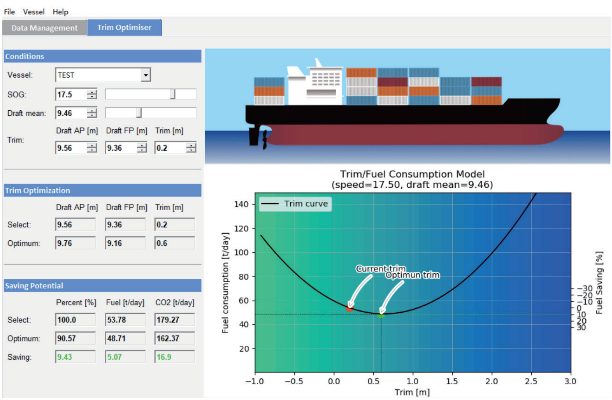


Figure 5-6 Snapshot of *TrimOptimiser Window*

Annex 1
Consolidated Chapter 4 of MARPOL Annex VI

Updated on 30 July 2019 including provisions entering into force on 1 September 2019

Chapter 4 – Regulations on energy efficiency for ships

Regulation 19

Application

1 This chapter shall apply to all ships of 400 gross tonnage and above.

2 The provisions of this chapter shall not apply to:

.1 ships solely engaged in voyages within waters subject to the sovereignty or jurisdiction of the State the flag of which the ship is entitled to fly. However, each Party should ensure, by the adoption of appropriate measures, that such ships are constructed and act in a manner consistent with the requirements of chapter 4 of this Annex, so far as is reasonable and practicable.

.2 ships not propelled by mechanical means, and platforms including

FPSOs and FSUs and drilling rigs, regardless of their propulsion.

3 Regulations 20 and 21 of this Annex shall not apply to ships which have non-conventional propulsion, except that regulations 20 and 21 shall apply to cruise passenger ships having non-conventional propulsion and LNG carriers having conventional or non-conventional propulsion, delivered on or after 1 September 2019, as defined in paragraph 43 of regulation 2. Regulations 20 and 21 shall not apply to cargo ships having ice-breaking capability.

4 Notwithstanding the provisions of paragraph 1 of this regulation, the Administration may waive the requirement for a ship of 400 gross tonnage and above from complying with regulations 20 and 21 of this Annex.

5 The provision of paragraph 4 of this regulation shall not apply to ships of 400 gross tonnage and above:

.1 for which the building contract is placed on or after 1 January 2017; or

.2 in the absence of a building contract, the keel of which is laid or which is at a similar stage of construction on or after 1 July 2017; or

.3 the delivery of which is on or after 1 July 2019; or

.4 in cases of a major conversion of a new or existing ship, as defined in regulation 2.24 of this Annex, on or after 1 January 2017, and in which regulations 5.4.2 and 5.4.3 of this Annex apply.

6 The Administration of a Party to the present Convention which allows application of paragraph 4, or suspends, withdraws or declines the application of that paragraph, to a ship entitled to fly its flag shall forthwith communicate to the Organization for circulation to the Parties to the present Protocol particulars thereof, for their information.

Regulation 20

Attained Energy Efficiency Design Index (Attained EEDI)

1 The attained EEDI shall be calculated for:

.1 each new ship;

.2 each new ship which has undergone a major conversion; and

.3 each new or existing ship which has undergone a major conversion, that is so extensive that the ship is regarded by the Administration as a newly constructed ship,

which falls into one or more of the categories in regulations 2.25 to 2.35, 2.38 and 2.39 of this Annex. The attained EEDI shall be specific to each ship and shall indicate the estimated performance of the ship in terms of energy efficiency, and be accompanied by the EEDI technical file that contains the information necessary for the calculation of the attained EEDI and that shows the process of calculation. The attained EEDI shall be verified, based on the EEDI technical file, either by the Administration or by any organization duly authorized by it[*].

2 The attained EEDI shall be calculated taking into account the guidelines developed by the Organization[†].

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* Refer to the Guidelines for the authorization of organizations acting on behalf of the Administration (resolution A.739(18), as amended by resolution MSC.208(81)), and the Specifications on the survey and certification functions of recognized organizations acting on behalf of the Administration (resolution A.789(19), as may be amended).

† Refer to 2018 Guidelines on the method of calculation of the Energy Efficiency Design Index (EEDI) for new ships (resolution MEPC.308(73)).

Regulation 21

Required EEDI

1 For each:

.1 new ship;

.2 new ship which has undergone a major conversion; and

.3 new or existing ship which has undergone a major conversion that is so extensive that the ship is regarded by the Administration as a newly constructed ship,

which falls into one of the categories defined in regulations 2.25 to 2.31, 2.33 to 2.35, 2.38 and 2.39 and to which this chapter is applicable, the attained EEDI shall be as follows:

$$\text{Attained EEDI} \leq \text{Required EEDI} = (1\text{-}X/100) \times \text{reference line value}$$

where X is the reduction factor specified in Table 1 for the required EEDI compared to the EEDI reference line.

2 For each new and existing ship that has undergone a major conversion which is so extensive that the ship is regarded by the Administration as a newly constructed ship, the attained EEDI shall be calculated and meet the requirement of paragraph 21.1 with the reduction factor applicable corresponding to the ship type and size of the converted ship at the date of the contract of the conversion, or in the absence of a contract, the commencement date of the conversion.

Table 1. Reduction factors (in percentage) for the EEDI relative to the EEDI reference line

Ship Type	Size	Phase 0 1 Jan 2013 – 31 Dec 2014	Phase 1 1 Jan 2015 – 31 Dec 2019	Phase 2 1 Jan 2020 – 31 Dec 2024	Phase 3 1 Jan 2025 and onwards
Bulk carrier	20,000 DWT and above	0	10	20	30
	10,000 – 20,000 DWT	n/a	0-10	0-20*	0-30*
Gas carrier	10,000 DWT and above	0	10	20	30
	2,000 – 10,000 DWT	n/a	0-10*	0-20*	0-30*
Tanker	20,000 DWT and above	0	10	20	30
	4,000 – 20,000 DWT	n/a	0-10*	0-20*	0-30*
Container ship	15,000 DWT and above	0	10	20	30
	10,000 – 15,000 DWT	n/a	0-10*	0-20*	0-30*
General Cargo ships	15,000 DWT and above	0	10	15	30
	3,000 – 15,000 DWT	n/a	0-10*	0-15*	0-30*
Refrigerated cargo carrier	5,000 DWT and above	0	10	15	30
	3,000 – 5,000 DWT	n/a	0-10*	0-15*	0-30*
Combination carrier	20,000 DWT and above	0	10	20	30
	4,000 – 20,000 DWT	n/a	0-10*	0-20*	0-30*
LNG carrier***	10,000 DWT and above	n/a	10**	20	30
Ro-ro cargo ship (vehicle carrier)***	10,000 DWT and above	n/a	5**	15	30
Ro-ro cargo ship***	2,000 DWT and above	n/a	5**	20	30
	1,000 – 2,000 DWT	n/a	0-5***	0-20*	0-30*

Ship Type	Size	Phase 0 1 Jan 2013 – 31 Dec 2014	Phase 1 1 Jan 2015 – 31 Dec 2019	Phase 2 1 Jan 2020 – 31 Dec 2024	Phase 3 1 Jan 2025 and onwards
Ro-ro passenger ship***	1,000 DWT and above	n/a	5**	20	30
	250 – 1,000 DWT	n/a	0-5***	0-20*	0-30*
Cruise passenger ship*** having non-conventional propulsion	85,000 GT and above	n/a	5**	20	30
	25,000 – 85,000 GT	n/a	0-5***	0-20*	0-30*

* Reduction factor to be linearly interpolated between the two values dependent upon ship size. The lower value of the reduction factor is to be applied to the smaller ship size.

** Phase 1 commences for those ships on 1 September 2015.

*** Reduction factor applies to those ships delivered on or after 1 September 2019, as defined in paragraph 43 of regulation 2.

Note: n/a means that no required EEDI applies.

3 The reference line values shall be calculated as follows:

$$\text{Reference line value} = a \cdot b^{-c}$$

where a, b and c are the parameters given in Table 2.

Table 2. Parameters for determination of reference values for the different ship types

Ship type defined in regulation 2	a	b	c
2.25 Bulk carrier	961.79	DWT of the ship	0.477
2.26 Gas carrier	1120.00	DWT of the ship	0.456
2.27 Tanker	1218.80	DWT of the ship	0.488
2.28 Container ship	174.22	DWT of the ship	0.201
2.29 General cargo ship	107.48	DWT of the ship	0.216
2.30 Refrigerated cargo carrier	227.01	DWT of the ship	0.244
2.31 Combination carrier	1219.00	DWT of the ship	0.488

Ship type defined in regulation 2	a	b	c
2.33 Ro-ro cargo ship (vehicle carrier)	(DWT/GT)-0.7·780.36 where DWT/GT<0.3	DWT of the ship	0.471
	1812.63 where DWT/GT≥0.3		
2.34 Ro-ro cargo ship	1405.15	DWT of the ship	0.498
	1686.17*	DWT of the ship where DWT≤17,000* 17,000 where DWT > 17,000*	
2.35 Ro-ro passenger ship	752.16	DWT of the ship	0.381
	902.59*	DWT of the ship where DWT≤10,000* 10,000 where DWT > 10,000*	
2.38 LNG carrier	2253.7	DWT of the ship	0.474
2.39 Cruise passenger ship having non-conventional propulsion	170.84	GT of the ship	0.214

* to be used from phase 2 and thereafter.

4 If the design of a ship allows it to fall into more than one of the ship type definitions specified in table 2, the required EEDI for the ship shall be the most stringent (the lowest) required EEDI.

5 For each ship to which this regulation applies, the installed propulsion power shall not be less than the propulsion power needed to maintain the manoeuvrability of the ship under adverse conditions as defined in the guidelines to be developed by the Organization[1].

6 At the beginning of Phase 1 and at the midpoint of Phase 2, the Organization shall review the status of technological developments and, if proven necessary, amend the time periods, the EEDI reference line parameters for relevant ship types and reduction rates set out in this regulation.

1 Refer to 2013 Interim guidelines for determining minimum propulsion power to maintain the manoeuvrability of ships in adverse conditions (resolution MEPC.232(65), as amended by resolutions MEPC.255(67) and MEPC.262(68); consolidated text: MEPC.1/Circ.850/Rev.2).

Regulation 22

Ship Energy Efficiency Management Plan (SEEMP)

1 Each ship shall keep on board a ship specific Ship Energy Efficiency Management Plan (SEEMP). This may form part of the ship's Safety Management System (SMS).

SEE INTERPRETATION 4 of MEPC.1/Circ.795/Rev.4

2 On or before 31 December 2018, in the case of a ship of 5,000 gross tonnage and above, the SEEMP shall include a description of the methodology that will be used to collect the data required by regulation 22A.1 of this Annex and the processes that will be used to report the data to the ship's Administration.

SEE INTERPRETATION 13 of MEPC.1/Circ.795/Rev.4

3 The SEEMP shall be developed taking into account guidelines adopted by the Organization*.

SEE INTERPRETATION 13 of MEPC.1/Circ.795/Rev.4

Regulation 22A

Collection and reporting of ship fuel oil consumption data

1 From calendar year 2019, each ship of 5,000 gross tonnage and above shall collect the data specified in appendix IX to this Annex, for that and each subsequent calendar year or portion thereof, as appropriate, ac-

* Refer to 2016 Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP) (resolution MEPC.282(70)).

cording to the methodology included in the SEEMP.

SEE INTERPRETATION 14 of MEPC.1/Circ.795/Rev.4

2 Except as provided for in paragraphs 4, 5 and 6 of this regulation, at the end of each calendar year, the ship shall aggregate the data collected in that calendar year or portion thereof, as appropriate.

3 Except as provided for in paragraphs 4, 5 and 6 of this regulation, within three months after the end of each calendar year, the ship shall report to its Administration or any organization duly authorized by it[2], the aggregated value for each datum specified in appendix IX to this Annex, via electronic communication and using a standardized format to be developed by the Organization[3].

4 In the event of the transfer of a ship from one Administration to another, the ship shall on the day of completion of the transfer or as close as practical thereto report to the losing Administration or any organization duly authorized by it[$$], the aggregated data for the period of the calendar year corresponding to that Administration, as specified in appendix IX to this Annex and, upon prior request of that Administration, the disaggregated data.

5 In the event of a change from one Company to another, the ship shall on the day of completion of the change or as close as practical thereto report to its Administration or any organization duly authorized by it[$$], the aggregated data for the portion of the calendar year corresponding to the Company, as specified in appendix IX to this Annex and, upon request of its Administration, the disaggregated data.

2 Refer to Guidelines for the authorization of organizations acting on behalf of the Administration (resolution A.739(18), as amended by resolution MSC.208(81)), and the Specifications on the survey and certification functions of recognized organizations acting on behalf of the Administration (resolution A.789(19), as may be amended).

3 Refer to 2016 Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP) (resolution MEPC.282(70)).

6 In the event of change from one Administration to another and from one Company to another concurrently, paragraph 4 of this regulation shall apply.

7 The data shall be verified according to procedures established by the Administration, taking into account guidelines to be developed by the Organization[4].

8 Except as provided for in paragraphs 4, 5 and 6 of this regulation, the disaggregated data that underlies the reported data noted in appendix IX to this Annex for the previous calendar year shall be readily accessible for a period of not less than 12 months from the end of that calendar year and be made available to the Administration upon request.

SEE INTERPRETATION 15 of MEPC.1/Circ.795/Rev.4

9 The Administration shall ensure that the reported data noted in appendix IX to this Annex by its registered ships of 5,000 gross tonnage and above are transferred to the IMO Ship Fuel Oil Consumption Database via electronic communication and using a standardized format to be developed by the Organization not later than one month after issuing the Statements of Compliance of these ships.

10 On the basis of the reported data submitted to the IMO Ship Fuel Oil Consumption Database, the Secretary-General of the Organization shall produce an annual report to the Marine Environment Protection Committee summarizing the data collected, the status of missing data, and such other relevant information as may be requested by the Committee.

11 The Secretary-General of the Organization shall maintain an anonymized database such that identification of a specific ship will not be possible. Parties shall have access to the anonymized data strictly for their analysis and consideration.

4 Refer to 2017 Guidelines for Administration verification of ship fuel oil consumption data (resolution MEPC.292(71)).

12 The IMO Ship Fuel Oil Consumption Database shall be undertaken and managed by the Secretary-General of the Organization, pursuant to guidelines to be developed by the Organization[5].

Regulation 23

Promotion of technical co-operation and transfer of technology relating to the improvement of energy efficiency of ships[6]

1 Administrations shall, in co-operation with the Organization and other international bodies, promote and provide, as appropriate, support directly or through the Organization to States, especially developing States, that request technical assistance.

2 The Administration of a Party shall co-operate actively with other Parties, subject to its national laws, regulations and policies, to promote the development and transfer of technology and exchange of information to States which request technical assistance, particularly developing States, in respect of the implementation of measures to fulfil the requirements of chapter 4 of this Annex, in particular regulations 19.4 to 19.6.

Chapter 5 – Verification of compliance with the provisions of this annex

Regulation 24

5 Refer to 2017 Guidelines for the development and management of the IMO Ship Fuel Oil Consumption Database (resolution MEPC.293(71)).

6 Refer to Promotion of technical co-operation and transfer of technology relating to the improvement of energy efficiency of ships (resolution MEPC.229(65)), and Model Agreement between Governments on technological cooperation for the implementation of the regulations in chapter 4 of MARPOL Annex VI (MEPC.1/Circ.861)

Application

Parties shall use the provisions of the Code for Implementation in the execution of their obligations and responsibilities contained in this Annex.

Regulation 25

Verification of compliance

1 Every Party shall be subject to periodic audits by the Organization in accordance with the audit standard to verify compliance with and implementation of this Annex.

2 The Secretary-General of the Organization shall have responsibility for administering the Audit Scheme, based on the guidelines developed by the Organization*.

3 Every Party shall have responsibility for facilitating the conduct of the audit and implementation of a programme of actions to address the findings, based on the guidelines developed by the Organization*.

4 Audit of all Parties shall be:

.1 based on an overall schedule developed by the Secretary-General of the Organization, taking into account the guidelines developed by the Organization*; and

.2 conducted at periodic intervals, taking into account the guidelines developed by the Organization*.

---

* Refer to the Framework and Procedures for the IMO Member State Audit Scheme (resolution A.1067(28)).

APPENDIX VIII

Form of International Energy Efficiency (IEE) Certificate

INTERNATIONAL ENERGY EFFICIENCY CERTIFICATE

Issued under the provisions of the Protocol of 1997, as amended, to amend the International Convention for the Prevention of Pollution by Ships, 1973, as modified by the Protocol of 1978 related thereto (hereinafter referred to as "the Convention") under the authority of the Government of:

....

(Full designation of the Party)

by..

(Full designation of the competent person or organization authorized under the provisions of the Convention)

Particulars of ship*

Name of ship..

Distinctive number or letters...

Port of registry...

Gross tonnage..

IMO Number†..

* Alternatively, the particulars of the ship may be placed horizontally in boxes.

† In accordance with IMO ship identification number scheme (resolution A.1078(28)).

THIS IS TO CERTIFY:

1 That the ship has been surveyed in accordance with regulation 5.4 of Annex VI of the Convention; and

2 That the survey shows that the ship complies with the applicable requirements in regulation 20, regulation 21 and regulation 22.

Completion date of survey on which this Certificate is based:............................
(dd/mm/yyyy)

Issued at...
(Place of issue of certificate)

(dd/mm/yyyy):.............................. ....
(Date of issue) *(Signature of authorized official issuing the certificate)*

(Seal or stamp of the authority, as appropriate)

Supplement to the International Energy Efficiency Certificate

(IEE Certificate)

RECORD OF CONSTRUCTION RELATING TO ENERGY EFFICIENCY

Notes:

1 This Record shall be permanently attached to the IEE Certificate. The IEE Certificate shall be available on board the ship at all times.

2 The Record shall be at least in English, French or Spanish. If an official language of the issuing Party is also used, this shall prevail in case of a dispute or discrepancy.

3 Entries in boxes shall be made by inserting either: a cross (x) for the answers “yes” and “applicable”; or a dash () for the answers “no” and “not applicable”, as appropriate.

4 Unless otherwise stated, regulations mentioned in this Record refer to regulations in Annex VI of the Convention, and resolutions or circulars refer to those adopted by the International Maritime Organization.

1 Particulars of ship

1.1 Name of ship..

1.2 IMO number...

1.3 Date of building contract...

1.4 Gross tonnage..

1.5 Deadweight ....

1.6 Type of ship*..

2 Propulsion system

2.1 Diesel propulsion .... ☐

2.2 Diesel-electric propulsion.. ☐

2.3 Turbine propulsion... ☐

2.4 Hybrid propulsion .... ☐

2.5 Propulsion system other than any of the above .... ☐

3 Attained Energy Efficiency Design Index (EEDI)

3.1 The Attained EEDI in accordance with regulation 20.1 is calculated based on the information contained in the EEDI technical file which also shows the process of calculating the Attained EEDI.................. ☐

The Attained EEDI is.................................... grams-CO_2/tonne-mile

3.2 The Attained EEDI is not calculated as:

3.2.1 the ship is exempt under regulation 20.1 as it is not a new ship as defined in regulation 2.23.. ☐

3.2.2 the type of propulsion system is exempt in accordance with regulation 19.3.. ☐

* Insert ship type in accordance with definitions specified in regulation 2. Ships falling into more than one of the ship types defined in regulation 2 should be considered as being the ship type with the most stringent (the lowest) required EEDI. If ship does not fall into the ship types defined in regulation 2, insert "Ship other than any of the ship type defined in regulation 2".

3.2.3 the requirement of regulation 20 is waived by the ship's Administration in accordance with regulation 19.4..☐

3.2.4 the type of ship is exempt in accordance with regulation 20.1...........☐

4 Required EEDI

4.1 Required EEDI is:grams-CO_2/tonne-mile

4.2 The required EEDI is not applicable as:

4.2.1 the ship is exempt under regulation 21.1 as it is not a new ship as defined in regulation 2.23...☐

4.2.2 the type of propulsion system is exempt in accordance with regulation 19.3...☐

4.2.3 the requirement of regulation 21 is waived by the ship's Administration in accordance with regulation 19.4..☐

4.2.4 the type of ship is exempt in accordance with regulation 21.1...........☐

4.2.5 the ship's capacity is below the minimum capacity threshold in Table 1 of regulation 21.2...☐

5 Ship Energy Efficiency Management Plan

5.1 The ship is provided with a Ship Energy Efficiency Management Plan (SEEMP) in compliance with regulation 22......................................☐

6 EEDI technical file

6.1 The IEE Certificate is accompanied by the EEDI technical file in compliance with regulation 20.1...☐

6.2 The EEDI technical file identification/verification number ....

6.3 The EEDI technical file verification date...

THIS IS TO CERTIFY that this Record is correct in all respects.

Issued at...
(Place of issue of certificate)

(dd/mm/yyyy):.............................. ....
(Date of issue) *(Signature of authorized official issuing the certificate)*

(Seal or stamp of the authority, as appropriate)

APPENDIX IX

Information to be submitted to the IMO Ship Fuel Oil Consumption Database

Identity of the ship
IMO number

Period of calendar year for which the data is submitted
Start date (dd/mm/yyyy)
End date (dd/mm/yyyy)

Technical characteristics of the ship

Ship type, as defined in regulation 2 of this Annex or other (to be stated)

Gross tonnage (GT)[7]

Net tonnage (NT)[8]

Deadweight tonnage (DWT)[9]

Power output (rated power[10]) of main and auxiliary reciprocating internal combustion engines over 130 kW (to be stated in kW)

EEDI (if applicable)

Ice class[11]

Fuel oil consumption, by fuel oil type[12] in metric tonnes and methods used for collecting fuel oil consumption data

Distance travelled

Hours underway

SEE INTERPRETATION 14 of MEPC.1/Circ.795/Rev.4

7 Gross tonnage should be calculated in accordance with the International Convention on Tonnage Measurement of Ships, 1969.

8 Net tonnage should be calculated in accordance with the International Convention on Tonnage Measurement of Ships, 1969. If not applicable, note “N/A”.

9 DWT means the difference in tonnes between the displacement of a ship in water of relative density of 1025 kg/m3 at the summer load draught and the lightweight of the ship. The summer load draught should be taken as the maximum summer draught as certified in the stability booklet approved by the Administration or an organization recognized by it.

10 Rated power means the maximum continuous rated power as specified on the nameplate of the engine.

11 Ice class should be consistent with the definition set out in the International Code for ships operating in polar waters (Polar Code), (resolutions MEPC.264(68) and MSC.385(94)). If not applicable, note “N/A”.

12 As defined in the 2018 Guidelines on the method of calculation of the Attained Energy Efficiency Design Index (EEDI) for new ships (resolution MEPC.308(73), as amended) or other (to be stated).

APPENDIX X

Form of Statement of Compliance – Fuel Oil Consumption Reporting

STATEMENT OF COMPLIANCE – FUEL OIL CONSUMPTION REPORTING

Issued under the provisions of the Protocol of 1997, as amended, to amend the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 related thereto (hereinafter referred to as "the Convention") under the authority of the Government of:

....

(full designation of the Party)

by...

(full designation of the competent person or organization authorized under the provisions of the Convention)

Particulars of ship[13]

Name of ship...

Distinctive number or letters..

IMO Number[14] ....

Port of registry...

Gross tonnage...

THIS IS TO DECLARE:

1 That the ship has submitted to this Administration the data required by

13 Alternatively, the particulars of the ship may be placed horizontally in boxes.

14 In accordance with IMO ship identification number scheme (resolution A.1078(28)).

regulation 22A of Annex VI of the Convention, covering ship operations from (dd/mm/yyyy) through (dd/mm/yyyy); and

2 The data was collected and reported in accordance with the methodology and processes set out in the ship's SEEMP that was in effect over the period from (dd/mm/yyyy) through (dd/mm/yyyy).

This Statement of Compliance is valid until ....(dd/mm/yyyy)

Issued at...

(Place of issue of certificate)

(dd/mm/yyyy):.............................. ....

(Date of issue) *(Signature of authorized official issuing the certificate)*

(Seal or stamp of the authority, as appropriate)

Annex 2

List of international regulations related to the reduction of GHG emissions from ships (as of December 2018)

No.	Regulations	Remarks
1	Carbon Dioxide (CO_2) emissions from ships	Adopted by resolution 8 of the International Air Pollution Conference of Parties to MARPOL 73/78 in September 1997
2	IMO Policies and Practices related to the Reduction of Greenhouse Gas Emissions from Ships	Adopted by resolution A.963(23) on 5 December 2003
3	Amendments to MARPOL Annex VI, inclusion of a new chapter 4 on regulations on energy efficiency for ships	Adopted by resolution MEPC.203(62) on 15 July 2011 and entered into force on 1 January 2013
4	Promotion of technical co-operation and transfer of technology relating to the improvement of energy efficiency of ships	Adopted by resolution MEPC.229(65) on 17 May 2013
5	2013 Guidelines for calculation of reference lines for use with the energy efficiency design index (EEDI)	Adopted by resolution MEPC.231(65) on 17 May 2013

No.	Regulations	Remarks
6	2013 Guidance on treatment of innovative energy efficiency technologies for calculation and verification of the attained EEDI	Agreed by MEPC.1/Circ.815 on 17 May 2013
7	2013 Guidelines for calculation of reference lines for use with the Energy Efficiency Design Index (EEDI) for cruise passenger ships having non-conventional propulsion	Adopted by resolution MEPC.233(65) on 17 May 2013
8	2013 Interim guidelines for determining minimum propulsion power to maintain the manoeuvrability of ships in adverse conditions, as amended	Adopted by resolution MEPC.232(65) on 17 June 2013, as amended by resolution MEPC.255(67) on 17 October 2014 and resolution MEPC.262(68) on 15 May 2015, and a consolidated text circulated by MEPC.1/Circ.850/Rev.1 on 15 July 2015
9	2014 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships	Adopted by resolution MEPC.245(66) on 4 April 2014, as amended by resolution MEPC.263(68) on 15 May 2015
10	Amendments to MARPOL Annex VI and the NOx Technical Code 2008 (Amendments to regulations 2, 13, 19, 20 and 21 and the Supplement to the IAPP Certificate under MARPOL Annex VI and certification of dual-fuel engines under the NOx Technical Code 2008)	Adopted by resolution MEPC.251(66) on 4 April 2014
11	2014 Guidelines on survey and certification of the Energy Efficiency Design Index (EEDI)	Adopted by resolution MEPC.254(67) on 17 October 2014, as amended by resolution MEPC.261(68) on 15 May 2015 and a consolidated text circulated by MEPC.1/Circ.855/Rev.1 on 8 October 2015
12	Model Agreement between Governments on technological cooperation for the implementation of the regulations in chapter 4 of MARPOL Annex VI	Approved by MEPC.1/Circ.861 on 22 April 2016
13	Recommendation on exemption of ships not normally engaged on international voyages from the requirements in chapter 4 of MARPOL Annex VI	Approved by MEPC.1/Circ.863 on 22 April 2016
14	2016 Guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP)	Adopted by resolution MEPC.282(70) on 28 October 2016

No.	Regulations	Remarks
15	Roadmap for developing a comprehensive IMO strategy on the reduction of GHG emissions from ships	Approved by Annex 11 of MEPC 70/18/Add.1 on 28 October 2016
16	Amendments to MARPOL Annex VI related to the data collection system for fuel oil consumption of ships	Adopted by resolution MEPC.278(70) on 28 October 2016 and entered into force on 1 March 2018
17	2017 Guidelines for Administration verification of ship fuel oil consumption data	Adopted by resolution MEPC.292(71) on 7 July 2017
18	2017 Guidelines for the development and management of the IMO Ship Fuel Oil Consumption Database	Adopted by resolution MEPC.293(71) on 7 July 2017
19	Submission of data to the IMO data collection system of fuel oil consumption of ships from a State not Party to MARPOL Annex VI	Agreed by MEPC.1/Circ.871 on 7 July 2017
20	Sample format for the confirmation of compliance, early submission of the SEEMP part II on the ship fuel oil consumption data collection plan and its timely verification pursuant to regulation 5.4.5 of MARPOL Annex VI	Agreed by MEPC.1/Circ.876 on 13 April 2018
21	Amendments to MARPOL Annex VI (ECAs and required EEDI for ro-ro cargo and ro-ro passenger ships)	Adopted by resolution MEPC.301(72) on 13 April 2018
22	Initial IMO Strategy on reduction of GHG emissions from ships	Adopted by resolution MEPC.304(72) on 13 April 2018
23	2018 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships	Adopted by resolution MEPC.308(73) on 26 October 2018
24	Amendments to the 2014 Guidelines on survey and certification of the Energy Efficiency Design Index (EEDI)	Adopted by resolution MEPC.309(73) on 26 October 2018 and a consolidated text circulated by MEPC.1/Circ.855/Rev.2 (including Resolution MEPC.254(67) MEPC.261(68) and resolution MEPC.309(73))
25	Programme of follow-up actions of the Initial IMO Strategy on reduction of GHG emissions from ships up to 2023	Approved by Annex 9 of MEPC 73/19/Add.1 on 5 December 2018

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Funded by the European Union and implemented by the International Maritime Organization, the Global MTCC Network (GMN) – formally titled "Capacity Building for Climate Mitigation in the Maritime Shipping Industry" – initiative unites technology centres – Maritime Technology Cooperation Centres (MTCCs) – in targeted regions into a global network. MTCC-Asia, hosted by the Shanghai Maritime University, is the only centre in Asia within the framework of GMN in promoting technologies and operations to improve energy efficiency in the maritime sector and help navigate shipping into a low-carbon future.

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The International Maritime Organization (IMO) and European Union (EU) reached an agreement in December 2015 to establish Maritime Technology Cooperation Centres (MTCCs) in five regions, i.e. Asia, Africa, Latin America, Caribbean and Pacific. The overall objective is to enhance capacity building in mitigating climate change through the effective adoption of global efficient energy measures by way of technical mentorship, professional training, data collection, regional coordination in adhering to international regulations on energy efficiency of ships. In December 2016, following the win of one-year bidding competition, Shanghai Maritime University (SMU) entered into an agreement with IMO as the host institution of MTCC-Asia, which was then inaugurated in 15th May 2017. The center serves as a promoting hub in Asia for IMO-EU MTCC projects by providing innovative technologies in curbing greenhouse gas, sharing of technical expertise and discovering innovative ways to reduce the carbon emission from ships through conferences, workshops, maritime education and training, and technological co-operations and transfer.

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