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WORLD MARITIME UNIVERSITY
Malmö, Sweden

THE DEVELOPMENT OF AN OPERATIONAL KPI FOR ENERGY EFFICIENCY SHIP OPERATION

By
DANUJA WIJAYANTO
Indonesia

A dissertation submitted to the World Maritime University in partial fulfilment of the requirements for the reward of the degree of

MASTER OF SCIENCE
in
MARITIME AFFAIRS
(MARITIME ENERGY MANAGEMENT)

2020

Danuja Wijayanto, 2020
Declaration

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

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

........................

16 November 2020

Supervised by: Professor Aykut I. Ölcer

Head of Maritime Energy Management Specialization,
World Maritime University
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Abstract

Shipping is the most efficient transport mode with 4/5 cargo trade is carried through the ocean. Shipping considered as one of the contributors to GHG emissions because it still relies on fossil fuels. In 2012, shipping GHG emissions is 977 million tonnes CO$_2$e then it is increasing to 1,076 million tonnes CO$_2$e in 2018. The share of shipping emissions among global anthropogenic emissions also risen from 2.76% in 2012 to 2.89% in 2018.

As with the climate change effect more and more felt, while the trend of emission keeps rising, the shipping industries need to come up with some regulation to effectively reduce GHG emissions. IMO as the highest regime in international shipping comes with the policies to reduce GHG emissions. Recent developments show that the path to significant CO$_2$ reduction faces difficulties and the main obstacles are neither technical nor economic, but political. A more practical way to reduce GHG emissions from international shipping is needed.

An alternative Operational KPI proposed and developed in this research could be a way forward to introduce a more practical way to show and gain more effective results to reduce international shipping emissions. The developed Operational KPI might be an alternative to fill in the gap for operational evaluator. While most of the ship rating tools focuses on the emission caused by ships, the proposed operational KPI emphasizes efforts and measures to reduce fuel consumption on ship thus will has a potential to GHG emissions effectively. The developed operational KPI can be applied on any kind of ship; however, the scoring need to be tailored based on the ship type.

A case study show that a ship with a high score with the proposed Operational KPI might show its potential to reduce GHG emissions. The possible application of the proposed Operational KPI can be divided into four pillars. For ship-owners, the use in hybrid MBM mechanism, for port incentives, and for charterers/cargo owners.

Keywords: Ship Energy Efficiency, Operational Measures, Fuel Saving, GHG emissions, Ship Energy Rating.
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Chapter I

Introduction

1.1 Background

Maritime transportation is one of the transportation modes available beside land and air transportation. It serves as the backbone of globalized trade due to the fact that more than 4/5 cargo trade by volume is carried through the sea (UNCTAD, 2019). Shipping which acts as the main driver in maritime transport is the most efficient transport mode. It has a special feature called economies of scale. While air and other modes of transportation are much more restricted in terms of size, shipping may carry extraordinarily big quantities of goods, up to half a millions tons of cargo due to floating and moving on water (Shuo, 2019). In 2018, the total global maritime trade reached 11 billion tons. Despite several uncertainties exist, maritime trade is expected to grow at an average of 3.5% over the 2019-2024 period (UNCTAD, 2019).

Since shipping still relies on fossil fuels, it is still subjected to one of the contributors of Green House Gas (GHG) emissions. One of the most harmful substances among other GHGs produced by shipping activities is Carbon Dioxide (CO₂). It causes increasing in atmospheric temperature (Chen, Fei, & Wan, 2019). According to the Fourth International Maritime Organization (IMO) Greenhouse Gas Study, in 2018, total shipping emissions were approximately 1,056 million tonnes CO₂ and 1,076 million tonnes CO₂e for GHGs combining CO₂, CH₄ and N₂O. Emissions are projected to increase from about 90% of 2008 emissions in 2018 to 90-130% of 2008 emissions by 2050 for a range of plausible long-term economic and energy scenarios (Faber, et al., 2020).

One of the major factors which most likely affects shipping growth is environmental aspects. Environmental sustainability agenda has become a major strategy due to increased awareness of the impact of global warming. The environmental regulations are more and more affecting shipping market dynamics. This trend is believe to continue in 2019 and beyond (UNCTAD, 2019). Heitmann and Peterson in 2014 found that the shipping sector could contribute to global CO₂ emission reduction. They argue that the shipping sector emission is substantial and it needs to be regulated in order to be (partially) reduced. The Third IMO GHG study in
2014 recommended that further action on regulatory or market-driven improvements in efficiency and emissions is much more effective, and it may mitigate the emission growth (IMO, 2015).

The International Maritime Organization (IMO) is a specialized agency under the United Nations (UN) which has created a regulatory framework in order to achieve safety and security of shipping and the prevention of marine and atmospheric pollution by ships. One of the main conventions is the International Conventions for the Prevention of Pollution from Ship (MARPOL). It covers prevention of pollution of the marine environment by ships from operational or accidental causes. IMO has specific committees which deal with environmental issues, the Marine Environmental Protection Committee (MEPC). On its 62nd session MEPC meeting, IMO adopted a mandatory global GHG reduction regime for the International industry. It was adopted by Parties to MARPOL Annex VI (IMO, 2011).

The amendments added a new chapter 4 to Annex VI, which made mandatory the Energy Efficiency Design Index (EEDI) that applies for new ships and the Ship Energy Efficiency Management Plan (SEEMP) that applies for all ships. New definitions and the requirements for survey and certification, including the format for the International Energy Efficiency Certificate are the other amendments to Annex VI (IMO, 2011). The amendments also include IMO Data Collection and Reporting Framework. These regulations entered into force in 2019 mandating all ships to report the measurement of the ship's annual fuel consumption.

1.2 Problem Statement

IMO has two tracks in reducing GHG emissions. Track I consist of EEDI and SEEMP and Track II is Market-Based Measure (MBM) (Psarafitis, 2019). EEDI is the technical measure which aims to promote the use of more efficient ship design. It is a performance-based mechanism which is non-prescriptive that enables ship designers and builders to choose the most cost-efficient solutions for the ship as long as the required energy-efficiency level is attained. It applies to all of the new ships since 1st January 2013. It is expressed in grams of CO₂ per ship's unit work-mile. (IMO, 2011).
SEEMP is an operational measure that set a guideline to increase the energy-efficiency of a ship in a cost-effective option during its operation. Under the SEEMP, IMO also provides a voluntary tool called Energy Efficient Operational Indicator (EEOI) which can be set as monitoring tool of SEEMP (IMO, 2011).

Besides technical and operation approaches to address GHG emissions from international shipping, IMO is also trying to make MBM. During the Joint Singapore-IMO International Conference on Maritime Technology Transfer & Capacity Building in 2015, Dr. Edmund Hughes (the Head of Air Pollution and Energy Efficiency in the Marine Environment Division of the IMO) explained that MBM could provide an economic incentive for the maritime industry to increase energy efficiency and, potentially could generate funds depending on the measure.

Several problems have occurred within the regulation strategies prepared by IMO. In track I, while EEDI can be used to rate ships according to technical aspects, in operational aspects there are several issues regarding implementation of SEEMP and also EEOI as the indicator. In track II, the discussion of MBM has stopped, IMO shifted the discussion to fuel consumption monitoring, which is called IMO DCS. However, there are also several problem with the implementation and clashes with the EU MRV from the EU communities.

While the emissions keep rising from international shipping and the effect of GHGs are more and more felt, a more practical way to regulate shipping emissions is required to effectively alleviate GHG emissions from international shipping.

1.3 Motivation

A more practical way could be introducing ship rating to induce ship owners to adopt technological and operational measures to reduce GHG emissions. Emission reduction from shipping can be achieved with two commonly used categories: technical and operational. The technical categories emphasize technological measures, for example improving ship design efficiencies, improving propulsion and power system, application of cleaner or alternative fuels, "cold ironing" in ports, and renewable energy generation, such as kites. The tactical and operational categories aim to reduce emission through speed optimization, optimized weather routing, fleet management optimization, efficient supply chain management and other measures which impact logistical operations (Psaraftis, 2016).
In technical aspects, EEDI could be used for distinguishing ship with good environmental performance. In operational aspects, since there are lots of external factors economically and environmentally, there is an absence on how to rate ship energy efficiency in the operational aspect.

There are several voluntary schemes developed to define ship environment performance. Each of these uses its own indicator and tries to set an index from the emissions from ships. The examples are the Clean Cargo Working Group of the containership operators, the Clean Shipping Index of major cargo owners, the Environmental Ship Index of the International Association of Ports & Harbors, and the Existing Vessel Design Index of Rightship (Panagakos, Pessôa, Dessypris, Barfod, & Psaraftis, 2019).

This dissertation will examine strategies that may be implemented by shipping companies to achieve high efficiencies in operational aspects and make a Key Performance Indicator (KPI) from those strategies. It will induce ship owners to implement operational measures; therefore, it will effectively reduce GHG emissions.

1.4 Aim & Objectives

The aim of the dissertation is making KPI from the operational measures which can define the operational performance of a ship. This will be possible by achieving the following objectives:

1. Explain the problems within IMO regulations to reduce GHG emissions.
2. Explain the problems with SEEMP and EEOI.
3. Examine operational measures to reduce GHG emissions.
4. Construct the KPI.
5. Explain the possible application of the KPI.
1.5 Structure of Dissertation

This dissertation is structured as follows:
Chapter 1 covers the background, problem statement, motivation, aim and objectives, methodologies, and structure of the dissertation.
Chapter 2 explains the development of energy policy, current state of the environment, problems with SEEMP and EEOI, and several ship performance environment ratings.
Chapter 3 examines the operational measures, the development of the KPI, and several potential applicability of the developed Operational KPI.
Chapter 4 case studies and discussion on possible application of developed Operational KPI.
Chapter 5 gives conclusion and recommendations on further study.
Chapter II

Literature Review

2.1 The Development of the Shipping Environmental Policy

The effort to address international shipping emissions was started under the United Nations Framework Convention on Climate Change in 1992. The main challenge at that time was the convention was unable to allocate emissions from international shipping to individual state parties (Doelle & Chircop, 2019).

Then in 1997, the Kyoto Protocol committed state parties to reduce GHG emissions. There were 192 signatories; however, maritime transport and aviation were not included (Psaraftis, Decarbonization of maritime transport: to be or not to be?, 2019). Similarly with UNFCCC, it does not allocate emissions from international shipping to individual parties (Doelle & Chircop, 2019).

In 2015, the Paris Agreements brought all nations into a common cause to take serious action to fight climate change and adapt to its effect, with more support to assist developing countries to do so. Maritime transport and aviation were still left outside; however, the agreements give mandate to reduce GHG emissions for maritime transport to IMO and International Civil Aviation Organization (ICAO) for aviation (Psaraftis, Decarbonization of maritime transport: to be or not to be?, 2019).

Efforts by IMO before the Paris Agreements, can be divided into two tracks according to Psaraftis. Track one is the EEDI and track two is the MBM (Psaraftis, Decarbonization of maritime transport: to be or not to be?, 2019). In 2011, in the MEPC 62, the Energy Efficiency Design Index (EEDI) was made mandatory for new ships, and the Ship Energy Efficiency Management Plan (SEEMP) was adopted for all ships of 400 GRT and above. It was the first legally binding climate change regulation since the Kyoto Protocol for the shipping industry. It came into force as of 1 January 2013 (Lagouvardou, Psaraftis, & Zis, 2020).

The second track is MBM. The first assessment about potential use of MBM for reducing GHG emissions in shipping was conducted in the 1st GHG Study in 2000. However, the first discussion of MBM in the IMO started in 2010 (Lagouvardou, Psaraftis, & Zis, 2020). There were 11 MBM proposals at the MEPC 60 in March 2010. The proposal can be divided into: 1 proposal about levy on bunker fuels, 4 proposals about Emission Trading Scheme, 3 proposals of Hybrid MBM, and 3 other proposals.
focus on reduction through a port state mechanism, rebate mechanism, and “do-nothing” proposal. Then, an IMO Expert Group was created to make feasibility studies from the proposals. The members of the expert group were nominated by various member states and other organizations. The expert group produced the results but no recommendation. At MEPC 63, Greece submitted a proposal to keep the discussion of bunker levy and ETS; put on hold hybrid MBM’s; and remove other proposals. The result of the discussion was to keep all of the proposals under discussion. Developing countries such as: China, India, and Brazil, brought forward a draft Resolution on Technical Co-operation and Transfer of Technology. However, there was no consensus from the member states. The same happened with a proposal for an Impact Assessment Study on MBM. It was brought by Chairman of MEPC, but without consensus (Psaraftis, 2019).

One critical factor that has been a serious obstacle for any GHG emissions regulation planning is the difference in the principle. The respective role of fundamental principles of No More Favourable Treatment (NMFT) in the IMO Conventions and Common but Differentiated Responsibilities (CBDR) in multilateral agreements such as UNFCCC (Doelle & Chircop, 2019). There are also main arguments of the developing countries who are against GHG emissions reduction. The stance of these countries was that their obligation to reduce GHGs should be less stringent than that of developed countries. Another issue of political disagreement at the IMO is on how the funds collected by MBM could be used for developing countries. Several industries and ship-owners are also against ETS mainly for reasons associated with the ETS administrative burden and ETS mechanism. (Psaraftis, Decarbonization of maritime transport: to be or not to be?, 2019)

After that, some of the MBM proposals were merged, others reformulated, and some were withdrawn. The hybrid proposal from Japan and WSC was merged, the US proposal was reformulated, and the Bahamas proposal was reformulated and then withdrawn. In May 2013 at MEPC 65, the discussion about MBM was suspended, so the discussion for monitoring, reporting, and verification is started (Psaraftis, Decarbonization of maritime transport: to be or not to be?, 2019). At that time, the EU had already produced the EU MRV, so there are two schemes on collecting ship fuel oil consumption. EU seems to be moving full speed on the MBM front (Lagouvardou, Psaraftis, & Zis, 2020). The EU considers that IMO measures to achieve satisfactory
emission reductions from international shipping are not sufficient, therefore, EU implemented monitoring, reporting, and verification of CO₂ emissions, called MRV (M. & B., 2019). The MRV is first step toward the EU strategy to MBM measure. It also created pressure on IMO to produce effective policies to mitigate GHG emissions. In 2016, IMO followed the similar path but on a global scale, by introducing the Data Collection System (IMO DCS) (Lagouvardou, Psaraftis, & Zis, 2020). The EU MRV and IMO DCS are the first step to collect and analyse emission data to be the basis to further decide on setting the target to reduce GHG emissions (DNV GL, 2018).

2.1.1 EU MRV & IMO DCS

The EU MRV started when the European Commission (EC) included shipping emissions into its 2009 climate and energy package with the aim to reducing GHG emissions within the European Union (EU) (DNV GL, 2017). The EU MRV entered into force on 1 July 2015. The regulation requires ship owners and operators to report their CO₂ emissions for vessel larger than 5,000 GT. The coverage of this regulation is for voyages when at least one port of call is EU and European Economic Area (EEA) ports. The EU ports include EU Member States, Iceland and Norway. While the EEA ports are Acores, the Canary Island, French Guiana, Guadeloupe, Madeira, Martinique, Mayotte, Reunion, and Saint Martin (Verifavia Shipping, 2018). The data collection of MRV started on 1 January 2018 and the first data reporting was published on 30 June 2019.

The IMO DCS at IMO level, started when the debate for MBM stalled and then at the IMO 68th session on October 2015, IMO discussed the establishment of a global fuel consumption database as a first step to investigate and improve energy efficiency in maritime shipping (DNV GL, 2017). At MEPC 70 (October 2016) IMO adopted a data collection system called IMO DCS. The regulation requires all vessel larger than 5,000 GT engage in international voyages to report their fuel consumption. The IMO DCS entered into force on March 2018 and the data collection of IMO DCS started on 1 January 2019 (Verifavia Shipping, 2018).
Figure 1 is the timeline of EU MRV and IMO DCS. For the EU MRV, the first reporting period was conducted over the years of 2018, and on 30 June 2019 the data was publicly published by the European Commission. Meanwhile, the IMO DCS are entered into force through Chapter 4, Regulation 22A of MARPOL Annex VI. The IMO DCS are under Part II of the SEEMP; therefore, on 31 December 2019, it was assessed for compliance by flag states or Recognized Organization (RO) and the Certificate of Compliance was issued. In 2019, the IMO DCS started. Then in 2020 onwards companies will create annual fuel consumption (FOC) and report it to the flag states or RO to get the Statement of Compliance from the flag states and RO. (DNV GL, 2018).

Even though both schemes have similar objectives, there are several differences about EU MRV and IMO DCS (see Table 1).

Table 1 EU MRV & IMO DCS Differences (Verifavia, 2018)
Some of the differences apart from the applicability and the reporting period is about the mechanism of this scheme. The EU MRV requires 37 sections of separate documents. The format has already been prescribed by the European Commission. While the IMO DCS consists of 9 sections, integrated as part of the SEEMP Part II, the data collection and reporting methodology should be prescribed in Part II and be subject to confirmation of compliances. The parameter of the report is also different. The EU MRV requires fuel consumption at sea, fuel consumption at berth, carbon emissions, time spent at sea excluding anchorage, distance sailed, and transport work. IMO DCS requires total fuel consumption, distance travelled, and hours underway, and DWT is used as proxy cargo carried. There is a difference between EU MRV and IMO DCS scheme in the transport work, EU MRV used actual cargo while IMO DCS used DWT. The verification method is also different, EU MRV is verified by independent accredited verifiers (class societies or other) while IMO DCS is verified by flag administration or RO. The publication of data is also different, EU MRV is an openly public database while IMO DCS is an anonymous public database (DNV GL, 2017; Verifavia Shipping, 2018).

2.1.2 Clash of two system for collecting ship fuel oil consumption data

With both EU and IMO issued regulations which may look like to have one objective which is to reduce GHG emissions, the finality of the plan and the mechanism create several critiques. EU MRV the European Commission has tried to persuade IMO by adopting a new legal framework, aiming at accurately quantifying ship fuel consumption and CO2 emissions (M. & B., 2019). It means there is a clash over one way another even though both schemes have the same final objective. It also can be seen in the actual roadmap plan from both of the schemes.

The European Union seems to be moving really quickly on the MBM to alleviate GHG emissions. In 2017, The European Parliament (EP) vote that shipping will be included in the EU Emission Trading Scheme, in case that IMO has not included global regulation by 2021. It is part of the plan of the EU to come up with the plan of “European Green Deal”. The plan is to make the EU the first climate-neutral continent by 2050. Even though the decision to include shipping in ETS receives many objections from the ship owners, the European Commission refused to take the
ETS off the table. They still monitored the IMO process very carefully (Lagouvardou, Psaraftis, & Zis, 2020).

At MEPC 70, a roadmap for alleviating GHG has been developed by IMO. The plan is called IMO Strategy on reducing GHG. It represents the response of the shipping community to the global set out in Paris Agreement. The plan consists of short-term, medium-term, and long-term measures. The short-term measure consists of measures that aim to improve the energy efficiency of the existing ship and include the use of speed optimization, weather routing, and fleet management technique. The medium-term possibly include MBM which implements “the polluter pays” principle. The long-term include technological measures with low carbon and alternative fuels (Lagouvardou, Psaraftis, & Zis, 2020).

The ship-owners industries demand a full alignment of the EU MRV and the IMO DOCS. They stated that amendments proposed by EC do not fully align the EU MRV and IMO DCS (ECSA & ICS, 2019). Establishing unilateral legislation may causing another country to establish its own national MRV regulation, such as the Chinese "Regulation on Data Collection for Energy Consumptions of Ships" which came into force on 1st January 2019. This is something that an international body like IMO would avoid. Such patchwork could lead to jeopardizing global cooperation and action effort to reduce GHG emissions (ECSA & ICS, 2019).

Implementation of MRV and IMO DCS also presents a significant compliance challenge for ship-owners and operators. Some experts suggest to reduce the administrative burden and provide transparency (M. & B., 2019). Multiple reporting requirements for the shipping industry to be prevented (ECSA & ICS, 2019). The difference in both schemes such as the definition of transport work, verification method, reporting template, and per voyage reporting obligation & data confidentiality problem which may lead to data misuse, are also some reasons stated by the ship-owners community (ECSA & ICS, 2019). It is still unclear and has not yet decided whether how and when the two schemes will be converged (DNV GL, 2017).
2.1.3 Data Collection and Reliability Issues

In regards to data collecting, both EU MRV and IMO DCS prescribe four similar methods to monitor fuel consumption. A company may select any of the fuel consumption monitoring methods. Those monitoring methods are:

a. Method A: Bunker Delivery Note (BDN)
b. Method B: Regular Stocktaking from the bunker tanks
c. Method C: Reading from flowmeters
d. Method D: Direct measurement from exhaust gas outlet

However, there are several existences of potential data errors in some of the elements of the fuel consumption monitoring methods, equipment, and documentation (Rony, 2017). When using the BDN, certain quantity of fuel oil is lost during the filtration and draining of the fuel oil system. There is also a problem for the ship’s crew to ensure exact quantity received during bunkering. Ship’s crews often discover the shortage later when the BDN is signed and it is already too late.

When using stocktaking from the bunker tanks, manual soundings of the fuel tanks are the most common for assessing the tank content. Various factors such as the stability condition of the ship, shape of tanks and trueness of sounding pipe, measuring tape, knowledge of the person performing the task as well as state of the sea, as a vessel’s movement is the factor which can cause wrong readings.

Using the flowmeters also has several problems. There are many types of flowmeters that are on the market with a wide range of accuracy. It needs to be regularly calibrated and maintain to ensure precise reading. The direct measurement from exhaust gas also has errors. There is ±2.5% deviation from the engine maximum on the exhaust gas flow measuring instrument according to the NOx technical side as cited by Rony, 2017. The error from the measurement shows that there are issues with the reliability of data as it can be mistakenly input by shipping companies.

There is also an issue with intentional data misreporting about fuel consumption. Some crew often intentionally over-report fuel consumption so that they can sell on the black market for their advantage. It is also pointed out that another reason crew conducting these activities is because of insufficient fuel deliveries from fuel suppliers. Usually, Ship’s crew realize the deficiencies after leaving the port then they conceal the problem by the over-reporting daily fuel consumption to the shore
organization in the shipping company so that they avoid the risk of legal action in the case of a port state control who checking the vessel fuel tanks and the mandatory on-board fuel consumption and will take action if any discrepancies are identified. Lack of vessel flow meters on the fuel delivery line often causes two moral hazard problems: insufficient fuel deliveries from suppliers and misreporting of fuel consumption by crews (Poulsen & Johnson, 2016).

There are also cases where the ship operators or inshore fleet managers encourage the crew to underreport daily fuel consumption. Especially in time charter when the limit is exceeded in a single day to avoid any claims for charterer (Poulsen & Johnson, 2016).

2.1.4 Data Analysis Issues

The EU MRV and IMO DCS are the first steps to induce MBM. Therefore after the data gathering, it will be further to support the decision making on both regimes. One of the planned which explicitly states by the EU is fuel pricing at a later stage. For IMO, the discussion on how to implement it to MBM is suspended in 2013 and there is no reference in its agenda to future policy, leaving ambiguities (M. & B., 2019). Even in the medium-term of IMO GHG Strategy, the phrase "possibly include MBM’s by the IMO shows that the destiny of MBM remains unclear (Lagouvardou, Psaraftis, & Zis, 2020).

A study to evaluate the data processing from the EU MRV Regulation has been done by Panagakos, et. al in 2019. The study is trying to analyse the data analysis based on the data collected and using the indicators stipulated on the MRV, such as EEOI, AER, ISPI, and ESSH. The data were gathered for the dry bulk sector. The main conclusion is that the published indicator values are not sufficient to address the knowledge gap on energy efficiencies. The variation of the indicators is too wide to convey any meaningful message regarding energy efficiency. It also leaves a question at the end of the study on how can the energy efficiency of ships be benchmarked after all (Panagakos, Pessôa, Dessypris, Barford, & Psaraftis, 2019).

The report from the European Commission also stated the lesson learn from the first implementation of EU MRV. The indicators used to understand how ships are performing requires careful interpretations. There are a lot of fluctuating and influencing factors. EEOI is sensitive to cargo, difficult to compare with EEDI. Using
AER the result is better and can show the ship performance compare to the technical energy efficiency levels, but when using EEOI (using real cargo carried), the result is fluctuating and worse than their technical efficiency (EC, 2020).

Therefore from the study and the report, it shows the insufficiency of current indicators to be used for further policy process. Even though that there are positive notes with high expectations and trust in MRV, another challenge for MRV, and IMO DCS as well, is how to handle such extensive data and the type of “data-mining” tools to be used. It still a question that remains pending (Rony, Kitada, Dalakis, Ölçer, & Ballini, 2019). Handling such kind of data is also require capable human resource and infrastructure, therefore it creates another challenge with the cost of data collecting and processing.

2.1.5 Data Verification Issues

As mention earlier, the verification method of EU MRV and IMO DCS is different. EU MRV is verified by independently accredited verifiers while IMO DCS is verified by flag administration or RO (DNV GL, 2017; Verifavia Shipping, 2018). For EU MRV, an accredited body can be class societies or others.

Particularly for IMO DCS, the verification process is done by flag administration or RO then reported to IMO. The problem may arise on the vessel sailing under Flag of Convenience (FOC). FOC is a nickname for an open registry or international registry. It is a process that allows foreign-owned ships to fly a national flag for genuine reasons. Obtaining business and economic opportunities in shipping are some of the reasons (Hamad, 2016). While it comes with economic opportunities, FOC creates problems on several issues include allegations of corruption (BBC, 2014). When it comes to data verification of the IMO DCS, it needs certain mechanism which prevents data misreporting due to some bribery or corruption thus will jeopardize the aim to alleviate GHG emissions from the ship.
2.1.6 Carbon Leakage

Carbon leakage is a situation in which GHG emission in one region is increasing because of climate policies imposed in another region, therefore also leading to shifting production, investment, or energy flows (Lighthouse, 2020). It means business where transfer to other countries which have laxer constraints on GHG regulation. As consequence, it may lead to an increase in total emissions. Carbon leakage includes environmental and competitive impacts. Environmental impact is the result of emissions shifting to another region which has one without, or with different levels of carbon pricing. It may reduce or reverse the intended environmental outcome from certain regulations (Marcu, Egenhofer, Roth, & Wijnand Stoefs, 2013). Competitive impacts happen because of the change of trade patterns, market share, and investment patterns, which may lead to economic disadvantages (Zetterberg, Burtraw, Stensson, Paulie, & Roth, 2014).

Carbon leakages cause by asymmetrical climate policies, policies imposed in one region while other region has no or laxer climate policies and/or prices. The asymmetrical climate policies have the roots in the UNFCC and the concept of CBDR which in the interpretation resulted in a differentiation between parties in the Kyoto protocol (Marcu, Egenhofer, Roth, & Wijnand Stoefs, 2013).

The EU MRV as part of EU ETS may lead to carbon leakage because the ship can make an evasive stopover outside non-EU/EEA port to reduce ETS obligation since the scheme only covers the last leg of the journey from a non-EU/EEA port to an EU/EEA port and the first leg of the journey from an EU/EEA port to a non-EU/EEA port. However, research shows that those practices were legally not possible or cost-effective. A ship can make an evasive stop only if they carry commercial operations (loading-unloading cargo/passenger) in those ports. Because the definition of port calls is under EU MRV legislation is the port where ship conducts commercial activates. So for other purposes such as refuelling, supplies, crew changes, shelters cannot be used to avoid obligation under EU ETS (Transport & Environment, 2020).
Making evasive port calls prove to be more costly for ships (Figure 2). Therefore ship would benefit more for complying in terms of cost rather than avoid it (Transport & Environment, 2020).

EU ETS is one of the examples of a region GHG climate policies that may lead to carbon leakage. Research shows that it is practically not possible for ship-owners to evade from it, however, in the broader context carbon leakage may happen in other regions with respect to area. There is no best alternative when it comes to avoiding carbon leakage. Therefore, a global solution is a key to prevail losing effectiveness as well as economic convenience rather than towards short-sighted solutions, domestically oriented point of view (Antimiani, Costantini, Martini, Salvatici, & Tommasino, 2013).
2.2 States of Environment

2.2.1 Environment in General

A broad picture of climate change can be seen on the global climate change indicators. It indicates important information for the domains most relevant to climate change. The global climate change indicators are global mean surface temperature, atmospheric greenhouse gas concentrations, ocean heat content, global sea level, ocean acidification, sea-ice extent and the mass balance of glaciers and ice sheets (WMO, 2020).

![Graph showing global mean temperature over time](image)

*Figure 3 Global Mean Temperature (WMO, 2020)*

As it can be seen in Figure 3, the global mean temperature for 2019 was around 1.1 ± 0.1 °C above the 1850–1900 baseline, which was used as an approximation of preindustrial levels. The year 2019 is likely to be the second warmest on record (WMO, 2020).
As seen in Figure 4, in 2018, GHG mole fractions for major GHG reached new peaks with globally averaged mole fractions of CO2 at 407.8±0.1 ppm, CH4 at 1869±2 ppb and N2O at 331.1±0.1 ppb. The three GHG annual increases were larger than the increase in the previous year and the 10-year averaged growth rates. In 2019, according to real-time data from several locations, the global average is most likely continued to increase although it will not be available until late 2020 (WMO, 2020).

Further indication can be seen from the ocean. Due to GHG emissions, the oceans are getting warmer, keep rising, and containing more acid. Global ocean heat gain has increased in the upper (0–700 m) layer, and heat has been sequestered in the deeper ocean layers (0–2000 m) in the last quarter of the decade, compared to the historical heat uptake since 1960 (WMO, 2020).

The sea level also continued rising. In 2019, the global mean sea level reached its highest value since the beginning of the high-precision altimetry record (January 1993). The average of increment is estimated at 3.24 ± 0.3 mm yr\(^{-1}\) over the 27 year period; however, the increment has increased over that time (WMO, 2020).

It is also shown that, the ocean is getting more acid. Over the last 20 to 30 years observations show a clear decrease in average pH, with a decline of the average global surface ocean pH of 0.017–0.027 pH units per decade since the late 1980s (WMO, 2020).
Through the key indicator, it can be seen that the effect of GHG emission is keep happening. In the UNEP Emission Gap Report, a decade between 2010 until 2020 is considered as a decade lost. Despite scientific warning and political commitment of climate policies, essentially, there has been no real change in the global emissions (UNEP, 2019).

2.2.2 Emission from Shipping

From the 4th IMO GHG Study, the greenhouse gas (GHG) emissions – including carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O), expressed in CO₂e – of total shipping (international, domestic and fishing) have increased from 977 million tonnes in 2012 to 1,076 million tonnes in 2018 (9.6% increase) (Faber, et al., 2020). The detail per year can be seen in Table 2.

<table>
<thead>
<tr>
<th>Year</th>
<th>Global anthropogenic CO₂ emissions</th>
<th>Total shipping CO₂</th>
<th>Total shipping as a percentage of global</th>
<th>Voyage-based International shipping CO₂</th>
<th>Voyage-based International shipping as a percentage of global</th>
<th>Vessel-based International shipping CO₂</th>
<th>Vessel-based International shipping as a percentage of global</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>54,793</td>
<td>962</td>
<td>2.76%</td>
<td>701</td>
<td>2.01%</td>
<td>848</td>
<td>2.44%</td>
</tr>
<tr>
<td>2013</td>
<td>34,959</td>
<td>957</td>
<td>2.74%</td>
<td>654</td>
<td>1.96%</td>
<td>837</td>
<td>2.39%</td>
</tr>
<tr>
<td>2014</td>
<td>35,225</td>
<td>964</td>
<td>2.74%</td>
<td>651</td>
<td>1.93%</td>
<td>846</td>
<td>2.37%</td>
</tr>
<tr>
<td>2015</td>
<td>45,239</td>
<td>991</td>
<td>2.81%</td>
<td>700</td>
<td>1.99%</td>
<td>859</td>
<td>2.44%</td>
</tr>
<tr>
<td>2016</td>
<td>55,380</td>
<td>1,028</td>
<td>2.90%</td>
<td>727</td>
<td>2.05%</td>
<td>904</td>
<td>2.55%</td>
</tr>
<tr>
<td>2017</td>
<td>55,810</td>
<td>1,064</td>
<td>2.97%</td>
<td>746</td>
<td>2.08%</td>
<td>929</td>
<td>2.59%</td>
</tr>
<tr>
<td>2018</td>
<td>56,573</td>
<td>1,056</td>
<td>2.89%</td>
<td>740</td>
<td>2.02%</td>
<td>918</td>
<td>2.51%</td>
</tr>
</tbody>
</table>

CO₂ emissions can be seen in Table 2. In 2012, CO₂ emission were 962 million tonnes of CO₂ emissions while in 2018 this amount grew 9.3% to 1,056 million tonnes of CO₂ emissions. The share of shipping emissions among global anthropogenic emissions has risen from 2.76% in 2012 to 2.89% in 2018 (Faber, et al., 2020).
2.3 Problem with SEEMP and EEOI

2.3.1 SEEMP in General

As part of IMO’s mandatory regulation which came into force on January 2013, SEEMP has a finality to have a mechanism in place to improve ship energy efficiency by monitoring the performance over a certain period and using the EEOI (Energy Efficiency Operational Indicator) as a benchmark level (Ghaforian, 2018). A SEEMP must be developed by the company and seek to improve the ship’s energy efficiency through four steps: planning, implementation, monitoring and self-evaluation (Hansen, Rasmussen, & Lützen, 2020).

The SEEMP is intended, like ISO and any other management system which has been established, to be based on the PDCA cycle (Plan- Do- Check- Act) (Ghaforian, 2018).

2.3.2 SEEMP Ineffectiveness

A qualitative study conducted by Hansen et. al., explored the effectiveness of SEEMP found several issue with SEEMP implementation (Hansen, Rasmussen, & Lützen, 2020). Those issue are:

- Decisions made by the officers on board are based on goals defined by other stakeholders and sometimes the demand and goal are in conflict with goals regarding energy efficiency defined in SEEMP.
- Crew and shipping offices need to cooperate when developing SEEMP to adjust its content to the particular vessel, ensure the working pattern, and the crew fully understand and be aware of the goals defined.
- Seafarers and crews need to be supported by ship energy-efficient operation training. Implementation of SEEMP is challenging because several stakeholders are influencing ship operation.
- Creating “energy efficiency culture” is needed as well as “safety culture”.

The root cause analysis identifying SEEMP ineffectiveness are shown in Figure 5. The barriers against ineffectiveness can be describe in four category, such as
management, economic, uncertainty in EEOI and split incentives (Ghaforian, 2018).

1. **Managerial Barrier**

   *Lack of obligatory nature-comparison between SEEMP and ISM Code*

   If comparing SEEMP with other management systems which has been introduced to shipping, such as Safety Management System (ISM Code), Quality Management System (ISO 9001), Environmental Management System (ISO 14001) and Energy Management System (ISO 50001), SEEMP does not have an effective and properly structured management system in the shore-based organization. For example, in the ISM Code there is Designated Person Ashore (DPA) (Ghaforian, 2018).

   Since SEEMP is voluntary, the implementation will not be as effective as compulsory regulations. There is high quality and in detail training for personnel onboard and ashore for familiarization. In the ISM Code, the training and raising awareness were emphasized and all stakeholders took it seriously and the STCW requirements were also adjusted by safety concerns (Ghaforian, 2018).
Furthermore, there is no comprehensive audit scheme. A management system without an effective auditing scheme cannot be reviewed and evaluated for performance (Ghaforian, 2018).

Management Structure Gap between SEEMP and ISO 50001

Both SEEMP and ISO 50001 have been established based on the PDCA Cycle. ISO is a management system while SEEMP is a management plan. The management plan is a subsidiary of a management system, therefore SEEMP cannot be compared with ISO 50001. The content of the SEEMP is formulated by the shipping companies and targeted at specific vessels (Hansen, Rasmussen, & Lützen, 2020). Many shipping companies provide SEEMP for their vessels to comply with regulations but they do not establish an energy management system at the company level (Ghaforian, 2018).

There are also several issues regarding goal setting, goals and indicators which are not mandatory in SEEMP and there is no energy audit in the SEEMP scheme which makes it incomplete if compared to ISO 500001 (Ghaforian, 2018).

Another gap between SEEMP and ISO 50001 include the independence of the energy management department, lack of accountability due to frequent personnel turnover, the role of stakeholders, contractual arrangements and outsourcing, and the rigidity of the management system (Ghaforian, 2018).

Management of Human Resources

The success and effectiveness of energy efficiency technologies are at stake of abilities of their operators. Here the importance of the human element in energy efficiency is unfolded (Ghaforian, 2018).

2. Economic

Economic barriers include cost and uncertainties in the shipping industry and highly fluctuating fuel prices which may affect shipping. The low fuel price has
been the main reason for ineffectiveness of the SEEMP after 2013 (Ghaforian, 2018).

3. **Uncertainties in EEOI**

   EEOI acts as voluntary performance indicator in SEEMP. The problem is that the EEOI came with the high level of uncertainties due to external uncertainties in shipping operations such as weather condition, and hull roughness. The rolling average technique is utilized to dampen the high fluctuation in EEOI calculated figures. For checking phase in PDCA, rigid formulated PI is needed and EEOI makes SEEMP evaluation severely weakened (Ghaforian, 2018).

4. **Split Incentives**

   Split incentives is a barrier against energy efficiency in terms of asymmetrical information (Johnson & Andersson, 2016). In shipping, the problems comes with the nature of ship chartering. It is likely to occur because of divided responsibility between ship-owners and charterers. In time charter, charterers will pay for the fuels. Therefore, the ship-owners who invest in fuel efficiency measures cannot recoup their investment (Rehmatulla & Smith, 2015).

   Split incentives might also happen when two parties engaged in contract, they may have different goals and levels of information about energy efficiency. (Rehmatulla & Smith, 2015). A parties could be aware of the possibilities for using certain energy efficiencies; however, they did not implement it, because another parties bears the energy cost and might receive benefit because of the implementation. It may result in tenant-landlord issues in the building sector (Johnson & Andersson, 2016).
2.4 Ship Performance Rating

Defining ship environmental performance has increases with the raising awareness of environment aspects. This makes ships require to be seen as energy efficient ships. In the technical aspects there is EEDI which can distinguish ship with applied energy efficient devices, on the operational aspects there is no index or indicator which can be used as evaluator. Several initiatives have been made on how to rate performance of a vessel based on the emission level from ships.

Clean Cargo Working Group (CCWG)

Clean Cargo Working Group Carbon Emissions Accounting is an initiatives made by the Clean Cargo Working Group. BSR’s Clean Cargo Working Group (CCWG) is a global non-profit organization which consists of more than 250 member companies dedicated to environmental performance improvement. It only calculates CO2 emissions within the container segment industries (CCWG, 2015).

The CCWG CO2 methodology only includes CO2 emissions and no other GHG emissions (CO2 equivalents: CO2e). CO2 emissions were calculated from the number of containers on ships with the following method in Figure 6:

\[ \text{CO}_2 \text{ dry} = \frac{\text{IMO Carbonconversion factor} \times (\text{Total fuel consumption} - \text{Total reefer fuel consumption})}{(\text{dist. sailed} \times \text{vessel TEU capacity})} \]

\[ \text{CO}_2 \text{ reefer} = \text{CO}_2 \text{ dry} + \frac{\text{IMO Carbonconversion factor} \times \text{Total reefer fuel consumption}^{(**)}}{(\text{dist. sailed} \times \text{reefer TEU capacity})} \]

\[ \text{Total reefer fuel consumption} = \text{reefer TEU capacity} \times \text{reefer consumption per year (const.)} \times \frac{\text{days vessel operated}}{365} \]

*Figure 6 Container Emission Equation (CCWG, 2015)*

The CO2 emission from each container were multiply with the TEU conversion factor, distance and divided by 70%. CCWG has adopted 70 percent as an appropriate representative average of the global average utilization (CCWG, 2015). Vessels can be compared based since vessel operate on the same trade lane under identical operational and commercial circumstances and in principle deliver the same service to the shipper (CCWG, 2015).
Clean Shipping Index (CSI)

Clean Shipping Index is an independent reporting and labelling system of the environmental performance of ships and shipping companies. CSI is an index tool which consists of 25 basic questions on environmental performance of ships. It comprises CO$_2$ emissions, NOx emissions, SOx emissions, particulate matter emissions, chemical applied in the ship, and waste and water management (CSI, 2018). Regarding CO$_2$ emissions, CSI relies on the actual emissions per ship based on the reference line obtained from EEOI of the ship compared with EEOI$_{ref}$ obtained from the following method (Figure 7) (CSI, 2018):

\[
\text{EEOI}_{\text{adj}} = \frac{\text{EEOI}_{\text{adj}}}{\text{fuel factor} \times \text{payload ratio}}
\]

*Figure 7 CSI EEOI$_{adj}$ Equation (CSI, 2018)*

Environmental Ship Index

Environmental Ship Index is an index developed by World Port Climate Initiatives, a commitment which consists of fifty-five of the world’s key ports. It is part of WPCI initiation which aims to reduce GHG emissions and improve air quality in the shipping sector (WPCI, 2010). The ESI identifies seagoing ships that go beyond the current standards in reducing air emissions. The index is intended to be used by ports to promote clean ships, but can also be used by shippers and ship owners as a promotional instrument (WPCI, 2010).

\[
\text{ESI}_{\text{overall}} = \frac{1}{3.1} \left( 2 \times \text{ESI}_{\text{NOx}} + \text{ESI}_{\text{SOx}} + \text{RR}_{\text{CO$_2$}} \right)
\]

*Figure 8 ESI Equation (WPCI, 2010)*

The ESI comprises of NOx, SOx, and CO$_2$ evaluation following the equation in Figure 8. Regarding the CO$_2$ emission, it only gives points to ships that report on energy efficiency with 10 points (WPCI, 2010). Then on 2016, CO$_2$ emission are included, based on EEOI. 5 points can be collected if shipping companies report three
years of their ship EEOI, and maximum 10 additional points depending on the progress reported of this indicator (ITF, 2018).

RightShip

RightShip is a maritime risk management and environmental assessment organization which is located in London, Melbourne and Houston. It create RightShip’s Greenhouse Gas Emissions Rating (GHG Rating) which was adopted by the maritime industry to measure and recognize the relative CO2 output of individual vessels. The GHG Rating provides a framework for comparing the relative efficiency of ships, which enables users to select vessels with a lower CO2 footprint and fuel bill (RightShip, 2020).

The ship categorization based on EEDI or EVDI. The ship categories include bulk carriers, chemical tankers, container ships, crude and product tankers, cruise passenger and general cargo ships, LNG tankers, LPG tankers, refrigerated cargo ships and ro-ro cargo ships (RightShip, 2020).
Chapter III

The development of a new operational KPI.

3.1 Insufficiency of Technical Rating

Some of the ship rating performance use the technical rating such as EEDI to describe the environmental performance for ships. However, evaluating ship performance based only on the technical rating may not fully describe the performance of the ship. Data from more than 3000 ships through EU MRV is stipulated in the Figure 9 to give an example.

Figure 9 Technical Efficiency vs Annual Average CO₂
The data is obtained from the 2019 EU MRV and THETHIS-MRV. The data was made open publicly according to the EU MRV. The Figure 9 shows the technical efficiency of the ship (the Energy Efficiency Design Index (EEDI)) or the Estimated Index Value (EIV) in accordance with IMO Resolution MEPC.215 (63) expressed in gCO₂/tones nautical mile and the annual average CO₂ emissions per transport work expressed in g CO₂/tones nautical mile. The data compiled is for the bulk carrier segment.

As can be seen, when the data is sorted by annual total time at sea, the annual average CO₂ per transport work for each ship tends to be higher than the technical efficiency. Ship with good technical environmental performance (lowest in technical efficiency) cannot be distinguished with the ship with bad technical environmental performance (high in technical efficiency). Some ships with good technical efficiency pollute more while some ships with bad technical efficiency pollute less than their technical efficiency. This is because every ship has different routes, different sailing frequency, different size, and different environmental conditions. Therefore, it is not enough to justify a ship from its technical efficiency.

3.2 The Methodology of the Proposed Operational KPI

One of the fundamental categories of options for reducing emissions from shipping is improving energy efficiency. Improving energy efficiency means doing more useful work with the same energy consumption (IMO, 2009). Commonly, maritime emissions and reduction measures are divided into two main categories: technical and operations (Psarafitis, 2016). The proposed operational KPI is comprised of operational measures. It puts emphasis on rating the ship by the operational measure which is implemented on the ship.

The broadest study about technical and operational measures to reduce CO₂ emissions from ships was presented by Bouman et. al. The research presents the result of 150 studies which provide a comprehensive overview of the CO₂ emissions reduction potentials and measures (Bouman, Linstad, Rialland, & Stremman, 2017). The categorization of the measures with the CO₂ emission reduction potential is shown in Figure 10. The category of the measures was divided into five categories, i.e. hull design, power and propulsion system, alternative fuels, alternative energy sources, and operation.
Figure 10 CO₂ Emission Reduction Potential (Bourman et al., 2017)

The sub-category on the operational measures are:

a. Speed optimization, include operational speed and reduced speed;

b. Capacity utilization,

c. Voyage optimization, include advanced weather routing, route planning, and voyage execution;

d. Other operational measures, include trim/draft optimization, energy management, and optimized maintenance.
The potential CO₂ reduction from the study can be seen in Table 3.

*Table 3 Operational Measures (Bouman et. al., 2017)*

<table>
<thead>
<tr>
<th>Operational Measures</th>
<th>CO₂ Reduction Potential Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed Optimization</td>
<td>1-60 %</td>
</tr>
<tr>
<td>Capacity Utilization</td>
<td>5-50 %</td>
</tr>
<tr>
<td>Voyage Optimization</td>
<td>0.1-48 %</td>
</tr>
<tr>
<td>Other Operational Measures</td>
<td>1-10 %</td>
</tr>
</tbody>
</table>

Another study is also included to complete the list of the operational measures. In these studies shown in Table 4, the list of the operational measures are benchmarked using reduction on fuel oil consumption. The information was obtained from Global Maritime Energy Efficiency Partnerships (Glomeep).

*Table 4 Operational Measures (Glomeep, 2015)*

<table>
<thead>
<tr>
<th>Operational Measures</th>
<th>Main Engine Fuel Reduction Potential Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed Management</td>
<td>10%-50%</td>
</tr>
<tr>
<td>Trim and Draft Optimization</td>
<td>0.5%-3%</td>
</tr>
<tr>
<td>Weather Routing</td>
<td>0% to 5%</td>
</tr>
<tr>
<td>Hull Cleaning</td>
<td>1%-5%</td>
</tr>
<tr>
<td>Propeller Polishing</td>
<td>3%-4%</td>
</tr>
<tr>
<td>Autopilot Adjustment &amp; Use</td>
<td>0.25%-1.5%</td>
</tr>
</tbody>
</table>

The hull cleaning on the Glomeep information only accounts for hull cleaning in the port using diver or ROV. If the vessel has regular hull cleaning in dry-docks or shipyards, the reduction in fuel consumption could reach up to 17% (Adland, Cariou, Jia, & Wolff, 2018).

The CO₂ reduction range estimation used in Bouman et. al. are diverse and the research need to be examined one by one to see the assumption and the applicability of the research to be compared. Therefore, the categorization of operational measures to be used in the proposed Operational KPI follows the division from Bouman et. al, but in order to make the scoring, the main engine fuel reduction from Glomeep project is used. The Glomeep project is used because they provide energy efficiency technology information which comprises a description of the measure, the typical associated costs, expected savings, and applicable software on the operational measures (Glomeep, 2015).
The developed operational KPI can be seen in Table 5. The non-measurable will be categorize in management aspects and the measurable will be categorize in ship operational aspects. In the management aspect, the components of the KPI are applied in the energy management system and capacity utilization. The scoring on the management level is calculated only whether, on the company level, they implement energy management systems and capacity utilization or not. The components in the ship operational aspect are speed optimization, voyage optimization, trim/draft optimization, and optimize maintenance. The scoring on the ship operational aspect is based on the fuel consumption potential reduction.

<table>
<thead>
<tr>
<th>Operational KPI</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Management</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applied Energy Management System</td>
<td>100</td>
<td>(Max: 100)</td>
</tr>
<tr>
<td>Capacity Utilization</td>
<td>100</td>
<td>(Max: 100)</td>
</tr>
<tr>
<td><strong>Max Score</strong></td>
<td>100</td>
<td></td>
</tr>
<tr>
<td><strong>Ship Operational</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed Optimization</td>
<td>62</td>
<td>(Max: 62)</td>
</tr>
<tr>
<td>Voyage Optimization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weather Routing</td>
<td>6</td>
<td>(Max: 6)</td>
</tr>
<tr>
<td>Autopilot Adjustment Application</td>
<td>2</td>
<td>(Max: 2)</td>
</tr>
<tr>
<td>Trim/Draft Opt.</td>
<td>4</td>
<td>(Max: 4)</td>
</tr>
<tr>
<td>Opt. Maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hull Cleaning</td>
<td>21</td>
<td>(Max: 21)</td>
</tr>
<tr>
<td>Propeller Polishing</td>
<td>5</td>
<td>(Max: 5)</td>
</tr>
<tr>
<td><strong>Max Score</strong></td>
<td>100</td>
<td></td>
</tr>
<tr>
<td><strong>Total Score</strong></td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

The developed Operational KPI (DOKI) purpose is that, it may rate the ship based on its effort of implementing the measures to reduce fuel consumption in operation aspects. The main advantage is that it can be applied to all kinds of ships; however, it has to be adjusted based on the ship type because every ship type has different characteristics and different operation based on the logistic or economic aspects.
3.3 Component of the Developed Operational KPI

3.3.1 Applied Energy Management System

Applying energy management may have up to 10% of CO₂ reduction potential (Bourman, Linstad, Rialland, & Strømman, 2017). Shipping companies could be addressing energy efficiency by adopting a systematic energy management system (Johnson & Andersson, Barriers to energy efficiency in shipping, 2016). Some examples of many best practices for use in organizations to manage work with energy efficiency, such as:

- Danish Standard (DS 2403), introduced in 2001
- Swedish Standard “Program för energieffektivisering” (PFE)” (SS 62 77 50), introduced in 2003
- European Standard (EN 16001), introduced in 2009
- ISO 50 001 Energy Management System, introduced in 2011

While energy management system which made specifically for shipping are:

- IMO SEEMP, introduced in 2012
- OCIMF revised its TMSA and include energy efficiency, introduced in 2009

Particularly for SEEMP implementation, as already mention in Chapter 2, there are many issues related to the guideline and it needs to be improved to be fully effective (Johnson, Johansson, Andersson, & Södahl, 2013). It can be further developed by embedded SEEMP in the implementation of ISO 50001 (Melandis, 2012).

There is a module on IMO Train the Trainer (TTT) Course on Energy Efficient Ship Operation which aims to improve awareness, knowledge, and skills required of office-based staff and sea-based staff on ship energy management systems and plans and their implementation. It provides general information on shipping management systems, details of ISO 50001 on Energy Management System (EnMS), ship and company-related management systems and plans and specific tools for monitoring of ship energy performance including energy reviews and audits, performance monitoring, data collection, monitoring and reporting including the IMO
data collection and EU Monitoring, Reporting and Verification (MRV) (IMO, 2016). It will help shipping companies applied the energy management system which respects to comply with the regulatory aspect such as IMO DCS, SEEMP, and EU MRV

3.3.2 Capacity Utilization

Capacity utilization at vessel and fleet-level (fleet management) may bring up to 5-50% potential reduction of CO2 (Bouman, Linstad, Rialland, & Stromman, 2017). Vessel capacity utilization is to the share of a vessel’s total carrying capacity occupied by paying cargo. The cargo-carrying capacity is defined by the type of ship and may refer to, for instance, tonnes (bulk carriers), cubic meters (gas carriers), TEU (container vessels), or lane meters (RoRo vessels) (Adland, Jia, & Strandenes, 2018).

The effect on every type of ship could be different as the market is also different. Capacity utilization is dependent on the distance sailed, the fuel price, and the value of the cargo (Adland, Jia, & Strandenes, 2018). The factors which may affect capacity utilization (see Table 6) could be defined by external factors and internal factors (Styhre, 2010).

Table 6 Factors Affect Capacity Utilization (Styhre, 2010)

<table>
<thead>
<tr>
<th>Factors that affect capacity utilisation</th>
<th>Enhancement of capacity utilisation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>External factors</strong></td>
<td></td>
</tr>
<tr>
<td>Market factors</td>
<td></td>
</tr>
<tr>
<td>State of the market</td>
<td>Explore and understand the market</td>
</tr>
<tr>
<td>Available cargo in the market</td>
<td>Find cargo in low-volume sea leg or departure</td>
</tr>
<tr>
<td>Imbalances export/import</td>
<td>Cooperate and communicate with shipping companies</td>
</tr>
<tr>
<td>Daily or seasonal variations in demand</td>
<td></td>
</tr>
<tr>
<td>Cargo mix</td>
<td></td>
</tr>
<tr>
<td>Competition and cooperation</td>
<td></td>
</tr>
<tr>
<td>Customer factors</td>
<td></td>
</tr>
<tr>
<td>Variations in produced output</td>
<td>Stand by cargo</td>
</tr>
<tr>
<td>Late cancellations</td>
<td>Overbooking</td>
</tr>
<tr>
<td>Double booking</td>
<td>Price differentiation</td>
</tr>
<tr>
<td>No-show</td>
<td>Rescheduling of bookings</td>
</tr>
<tr>
<td>Information exchange</td>
<td>Improve information exchange</td>
</tr>
<tr>
<td>The schedule of the deep sea vessel</td>
<td></td>
</tr>
<tr>
<td>Delays of deep sea vessel</td>
<td></td>
</tr>
<tr>
<td>Port factors</td>
<td></td>
</tr>
<tr>
<td>Port capacity</td>
<td>Cooperate and communicate with ports</td>
</tr>
<tr>
<td>Infrastructure capacity</td>
<td>Improve cargo handling equipment</td>
</tr>
<tr>
<td>Port performance</td>
<td></td>
</tr>
<tr>
<td>Surrounding factors</td>
<td></td>
</tr>
<tr>
<td>Congestion</td>
<td>Route planning</td>
</tr>
<tr>
<td>Weather conditions</td>
<td>Lobbying</td>
</tr>
<tr>
<td>Regulation and legislation</td>
<td></td>
</tr>
<tr>
<td>Internal factors</td>
<td></td>
</tr>
<tr>
<td>Management factors</td>
<td></td>
</tr>
<tr>
<td>Planning, organising or leading</td>
<td>Cooperate and communicate within the company</td>
</tr>
<tr>
<td>Sailing schedule</td>
<td>Develop flexible capacity management</td>
</tr>
<tr>
<td>Vessel factors</td>
<td></td>
</tr>
<tr>
<td>Vessel design, size, and age</td>
<td>Change of sailing schedule</td>
</tr>
<tr>
<td>Stowage plans</td>
<td></td>
</tr>
<tr>
<td>Maintenance of the vessel</td>
<td>Develop suitable vessel design</td>
</tr>
<tr>
<td></td>
<td>Find the right type of cargo and customers</td>
</tr>
<tr>
<td></td>
<td>Improve storage plans</td>
</tr>
<tr>
<td></td>
<td>Improve transport units</td>
</tr>
</tbody>
</table>

* These factors are foremost related to feeder shipping.
Even though capacity utilization is much more depend on the external factors, regarding the developed operational KPI, capacity utilization could be described on how the company manages the internal factors. For management factors, the key aspects are good internal communication and cooperation. It includes the possibilities to use and develop the skills of planners, stevedores, and commercial teams, the cooperation between office workers and vessel crews, and the creation of an understanding of the overall business strategy among a company's employees. It will ultimately affect vessel capacity utilization (Styhre, 2010). Implementation ISO 9001 about Quality Management Systems (QMS) could be a way to help the challenges. Regarding the vessel factors implementation of Planned Maintenance Systems and stowage plan software could be the way to be an indicator of good capacity utilization.

3.3.3 Speed Optimization

Since ship resistance is directly correlated with the ship’s speed, speed optimization has relatively a high reduction in fuel consumption and significant emission reduction can be achieved. Up to 60% of potential CO₂ reduction can be achieved (Bouman, Linstad, Rialland, & Strommman, 2017). Although having the potential to reduce fuel consumption and emission, speed optimization practice comes with a trade-off. The ship will go slower, so it requires more time to complete the voyage. More time on voyage means that another operational cost may increase. Scheduling requirements from the charterer and weather conditions are other factors which need to be considered in speed optimization practices (Glomeep, 2015).

The speed optimization decision at the operational level also depends on fuel price, the state of the market (freight rate), inventory cost of the cargo, and dependency of fuel consumption on the payload. Therefore, practicing speed optimization effectively should consider the economic and environmental aspects (Psarafis & Kontovas, 2014).

However, the practice of speed optimization can be done by the company with conduct analysis with its ships and come with their strategies. Some software is available that may assist shipping company and staff to determine the ship’s speed.
- NAPA Voyage Optimization

NAPA Voyage Optimization is software for improving operational efficiency by optimizing route and speed profiles for any sea passage (NAPA, 2019).

- Kongsberg Vessel Performance Optimizer

The Kongsberg Vessel Performance concept provides a set of tools that enables ship owners and operators to manage their vessels in ways that are more economical and ecologically beneficial, in compliance with safety regulations (Kongsberg, 2014).

3.3.4 Voyage Optimization

Voyage optimization CO₂ emission potential reduction is up to 10%. It can be achieved through advanced weather routing, good route planning, and voyage execution (Bouman, Linstad, Rialland, & Stromman, 2017). The biggest potential could be realized in intercontinental trades and for larger ships since they sail longer and have more alternative routes. The effect of the reduction will be different for each type of ship (Glomeep, 2015).

Another way to optimize the voyage is application of autopilot. It is the use an automatic system to control the rudder on the vessel. The autopilot application may reduce the fuel consumption by holding the rudder movement so it may hold a steady course. Minimizing rudder movement may consequently reduce fuel consumption. This decreases the rudder movement and consequently reduces fuel consumption (Glomeep, 2015).

Some software comes with packages of speed optimization such as NAPA Voyage Optimization. It already includes weather conditions to choose the route and the speed. However, some software builds only particular system to facilitate navigational decision-making, such as the AdrenaShip and StormGeo NaviPlanner BVS. The system is estimated to cost $15,000 (USD) per ship to install. In-addition, annual subscriptions of $3,000 (USD) per ship are needed to keep the software up to date and get the latest weather information (Glomeep, 2015).
3.3.5 Trim/Draft Optimization

Trim/Draft Optimization CO₂ emission reduction potential is up to 5% (Bouman, Linstad, Rialland, & Strømman, 2017). Trim/Draft of the ship influences hull resistance; therefore, it will affect fuel consumption. By actively planning cargo loading, and thereby optimizing the trim and draft, a ship can save fuel and reduce the emissions accordingly (Glomeep, 2015).

There are several types of software available which may assist the ship’s crew to optimize the trim and draft. Additional equipment is required such as a better loading computer or a dedicated trim optimizer. Training for the crew is necessary so that the crew able are to use the equipment. Better trim and draft will reduce resistance and less engine power is required which leads to lower fuel consumption. Estimation $15,000 to $75,000 (USD) per ship is required for installation of the system and crew training depending on the type of system ranging from easy trim systems which are less expensive than complicated trim software. Once the equipment is installed, there is no additional operational cost (Glomeep, 2015).

3.3.6 Optimize Maintenance (Hull Cleaning & Propeller Polishing)

Cleaning the hull and propeller polishing is considered in optimizing maintenance which may have up to 5% of CO₂ emission reduction potential (Bouman, Linstad, Rialland, & Strømman, 2017). Cleaning the hull will remove biological roughness or fouling. Marine fouling can lead to increased drag and will increase ship resistance. As a result, it requires more power, more fuel consumption required for the power and it will increase emissions (Glomeep, 2015). Apart from the hull, regular polishing or coating of the propeller may maintain the propeller due to strain and cavitation damage which grow over time. It is recommended to perform this measure twice yearly (Glomeep, 2015).

A vessel may show the plan of the hull cleaning or hire a diver to clean the hull. For basic underwater cleaning the price is around $5,000 to $50,000 (USD) for hire diver or ROV (Glomeep, 2015).
3.4 Potential Application of the Developed Operational KPI for Ship-owners

The direct application of the developed Operational KPI is toward ship-owner and shipping companies. It can be used in the management level so that the companies may have the goal to apply energy efficiency measures. Having a goal will help shipping companies since there are lots of challenges in practicing energy efficiency.

The environmental concern has driven shipping industries to be more environmentally friendly. Particularly for air emission, international shipping accounts for about 3% of total GHG emissions but if no mitigation and the practice continues as business as usual (BAU), it would continue to rise. If shipping industries want to contribute to reducing global warming under the Paris Agreement, the sector must promote energy efficiency and emission reduction (Chen, Fei, & Wan, 2019).

There is research that have already investigated the effect of several technical and operational methods of reducing GHG emissions. 75% emission reduction is achievable with combinations of current technologies by 2050. Six groups of measures with the highest potential in mitigating CO2 are hull design, the economy of scale, power and propulsion (including energy-saving devices), speed, fuels, and alternative energy sources, and weather routing and scheduling (Bouman, Linstad, Rialland, & Strømman, 2017).

A study about the implementation of technical energy efficiency and CO2 emission was also conducted by Rehmatulla et al. They observed thirty energy efficiency and CO2 reduction technology implementations among ship owners and operators. They found that there is a good spread of implementation but only certain measures are implemented at a sufficient level. Those technologies with the highest implementation are the application of bulbous bow (technologies), the use of pre/post swirl devices (hydrodynamics), and engine tuning and engine de-rating as well as waste heat recovery system application (machinery). Although certain technologies have high implementation, this implementation only accounts for small energy efficiency gains. There are only a small number of applications for technologies having high potential for reducing CO2, such as the application of alternative fuels. If shipping wants to be in line with the decarbonization plan, it requires higher implementation of energy efficiency and CO2 reducing technologies than those only driven by current regulations (Rehmatulla, Calleja, & Smith, 2017)
The new regulation about energy efficiency has also made some researchers questioning whether ship owners are going to implement new innovative technologies in their new building projects or retrofit their ships due to this regulation. They conclude that EEDI does not induce ship owners to apply ship engine technologies or alternative fuels. Instead, they order ships with reduced design speed. SEEMP makes ship owners change to the dual-fuel engine rather than alternative energy systems (Laurence, Christa, Thierry, & Edwin, 2015).

Research which explores energy consumption monitoring in shipping companies was conducted by Poulsen et. al. The research found that the problem with energy consumption monitoring (ECM) in energy management practices in a shipping company is associated with data collection challenges, related to lack of real-time data; incentives for data misreporting, especially in time charter since the fuel paid by the charterers; data analysis problem, because there is noise in the data sets and shipping companies struggle to analyses due to lack of long time series especially for short term charterers; and feedback problems, where there was lack of connection between seafarers working on-board and the shore department (Poulsen & Johnson, 2016).

While there are researches that study technical and operational systems to reduce emission, in practice there are several challenges regarding the implementation of the technical and operational measures. There are several barriers to implement cost effective energy saving measures (Jafarzadeh & Utne, 2014). Shipping companies are hesitating to adopt technical and operational measures. This phenomenon is called the energy efficiency gap (Johnson & Andersson, 2016).

Jafarzadeh et al., have divided the barriers to energy efficiency into 7 groups. Those barriers are information barriers, economic barriers, intra-organizational barriers, inter-organizational barriers, technology barriers, policy barriers, and geographical barriers (Jafarzadeh & Utne, 2014).

Johnson et al., scrutinized the energy efficiency gap and divided it into market failures and non-market failures. Market failures include incomplete markets, imperfect competitions, and information asymmetries. The example of information asymmetries is split incentives, adverse selection, and moral hazard. They emphasize the information asymmetries and organizational barriers and found that barriers within shipping organizations are uncertainties and asymmetric information about the
effectiveness of the measures, fragmentation of different roles and actions concerning energy use, and organizational structures that lack learning and innovation (Johnson & Andersson, Barriers to energy efficiency in shipping, 2016).

Rehmatulla et al. found the energy efficiency gaps and divided them into three categories. Non-market failures, market failures, and organizational and behavior barriers. Non-market failures include heterogeneity, risk, hidden cost, and access and costs of capital. Market failures are information problems and split incentives. While behavioral and organizational include bounded rationality, inertia, values, and credibility and trust. Their analysis found that non-market failures were not obvious to explain energy efficiency gaps. On the other hand, it was found market failures correlated to the implementation of individual measures and can be an explanation for the efficiency gaps (Rehmatulla & Smith, 2015).

Ölcer et al., in their research, show that the barriers in energy efficiency include safety and reliability (whether the energy efficient method is reliable and does not compromise with safety), technical uncertainty (interaction between ship components after energy efficiency methods are implemented), behavioral barriers (interaction within the shipping organization and information dissemination in the organization), market constraints (split incentives), financial and economic constraints (investment cost, market condition, and fuel price), and complexity (the operation of energy efficiency measures as systems) (Ölcer & Kitada, 2016).

3.5 Other Potential Applications on the Developed Operational KPI

The application on the developed Operational KPI could be extended into several perspectives.

3.5.1 Hybrid MBM Mechanism

The Market-based measure is one of the measures which is introduced to alleviate GHG emissions. The mechanism in the MBMs includes the Emission Trading Scheme (ETS), International Fund Based, and some proposals about a mechanism to rating ships (Psaraftis, 2016). MBM uses prices or other economic variables to provide monetary incentives for polluters to reduce emissions (Lagouvardou, Psaraftis, & Zis, 2020).
There are 11 proposals under consideration related to MBM that were submitted to the IMO (IMO, 2010). Psaraftis divided the proposals into several categories. A “do-nothing proposal” which submitted by the Bahamas; Hybrid MBM Proposals submitted by US, Japan, and WSC; Jamaica’s proposal about measuring the amount of fuel consumed by the respective vessel on that voyage (not bunker suppliers) through levying a uniform emissions charge on all vessels calling at their respective port; the IUCN proposal about rebate mechanism; GHG Funds submitted together by Cyprus, Denmark, Liberia, Nigeria, the Marshall Islands, the Republic of Korea and IPTA; and ETS proposal was submitted by Norway, the UK, France, and Germany (Psaraftis, Green Maritime Transportation: Market Based Measures, 2016).

The hybrid proposals aim to rewarding ships that are supposed to be good environmentally. The US proposed Ship Efficiency and Credit Trading (SECT). It employs technology to create a simple, pragmatic, and cost-effective solution to reduce GHG emissions from existing ships using EEDI. Japan proposed the Leveraged Incentives Scheme (LIS) to improve the energy efficiency of ships through incentives which are collected on marine bunkers and are refunded to ships labelled as “good performance ships”. The benchmarking is based on good hardware reflected in EEDI and operate such hardware “wisely” reflected in EEOI. World Shipping Council (WSC) proposed “Establish a Vessel Efficiency System” measured by the EEDI (IMO, 2010).

In all three of the proposals, EEDI is proposed as a way to measure good environmental performance. A problem may occur when a ship with low EEDI (Good environmentally) is not the ship with the lowest CO2. It will emit more CO2 than another ship whose EEDI is higher. Other than that, EEDI is supposed to be used in new ships after 2013. Currently, there has been no discussion on applying EEDI to existing ships (Psaraftis, 2016).

With the EEOI several problems appeared, which makes it difficult to be used as a benchmarking indicator as there is a gap on how to evaluate the ship in operational aspects.

3.5.2 Port Incentives

Ports may have a role in initiating green maritime transition by using economic instruments as an environmental differentiator by those who implement green
solutions and those who not act accordingly (Mjelde, et al., 2019). The managing bodies in the port may induce the environmental performance of shipping. One option is to offer incentive for the shipping industry to be more environmentally-friendly; thus this will reduce the negative effects from shipping (COGEA, 2017).

Financial incentives could significantly reduce ship emission in ports and voyages (Mjelde, et al., 2019). Incentives are different from regulations because they give freedom to do something for the actors and be rewarded or penalized for their activity. In any sector, including environmental policy, financial incentives prove to be effective as they provide flexibility, require less enforcement than regulation, and may encourage the actors where mitigation is achievable with the lowest cost (ITF, 2018). Incentives from environmental charging can help make investing in greener technologies more profitable and, under certain conditions, shorten payback time on the investment by one or more years (COGEA, 2017).

A study by Mjelde et. al, found that port fees based on the vessel’s environmental performance could induce ship-owners to invest in green technologies and help reduce emissions into the air, in this case for cruise ships and with the application of LNG. Incentives may promote environmentally friendly maritime transport and may become an important market-based measure to reduce GHG and other harmful emissions. The research shows that to be a significant driver, rebates should be sufficiently large and offered by enough ports worldwide (Mjelde, et al., 2019).

Every port has a different scheme on how to implement the financial incentives to the ship. One of the schemes is by applying a green port fee based on green port indexes (ITF, 2018). It is easier for ports to rely on existing scoring or certification to measure the ship’s environmental performance, rather than developing new metrics (COGEA, 2017). There are over 50 initiatives of the index found (Sköld, 2019); however, only four main indexes are widely used: the Environmental Ship Index (ESI), the Green Award, the Clean Shipping Index (CSI), and the GHG Emissions Rating of RightShip (ITF, 2018). There are other indexes such as Blue Angel; however, it is not popular as the other initiatives because only one EU port is using the Blue Angel scheme (COGEA, 2017) and only one active vessel is using it (Sköld, 2019). There is also the Environmental Port Index, but it is only restricted for cruise ships. It is an exception that aims to reward low-emission cruise ships in port (Mjelde, et al., 2019).
Table 7 Comparison of Indexes (ITF, 2018)

<table>
<thead>
<tr>
<th>Index</th>
<th>Main Criteria</th>
<th>Main Target Group</th>
<th>Scores Determined by</th>
<th>CO2 Related Criteria</th>
<th>Weight of CO2 Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESI</td>
<td>NOx, SOx, CO2, shore power</td>
<td>Ports</td>
<td>Self-assessment ship-owners, some audits by ports</td>
<td>To report on EEOI datasets</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td>Safety, service quality and environmental</td>
<td>Ports, banks, maritime service</td>
<td>Audits and verification by Bureau Green Award</td>
<td>To assess current emission levels</td>
<td>marginal</td>
</tr>
<tr>
<td></td>
<td>performance</td>
<td>providers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSI</td>
<td>NOx, SOx, PM, CO2, chemicals, water and waste</td>
<td>Shipping companies, shippers, ports</td>
<td>Submission by carriers, verification by verification</td>
<td>Emissions compared to reference ship</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and authorities</td>
<td>companies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RightShip</td>
<td>Ship energy efficiency</td>
<td>Charterers, shippers, banks, ports,</td>
<td>RightShip based on variety of sources</td>
<td>EEDI or EVDI</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>terminals</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Most of these indexes in Table 7 are putting more weighting on local pollutants, not the GHG emissions. ESI and Green Award both only account for a small share of GHG emissions. ESI CO₂ criteria are only 10% of the total score and ESI only recently putting CO₂ emissions in their index (ITF, 2018).

ESI relies on self-declaration and does not require any data to be verified or certified by external auditors; the data are randomly checked for inconsistencies and obvious mistakes (COGEA, 2017). This also creates some issues: 12.5% of vessels were found to be non-compliant during the ESI audits. This meant that some ships were less environmentally friendly compared to their report by the shipping company. They only used the index to get the discount without actually making an effort to reduce emissions (ITF, 2018).

For Green Award, CO₂ emission is only marginal in this scheme, and shipowners are required to assess their current emission levels and “make efforts to reduce emissions based on that reference”. Green Award presents the widest focus
from all of the indexes. It takes fifty different criteria, from safety and service quality to environmental performance (ITF, 2018). It is quite extensive and includes both areas demanded through current international and national/regional regulations and issues that are not regulated. Therefore, the Green Award has received criticism from ship owners and is considered complicated by a study conducted by EMSA (Sköld, 2019). GA and ESI actually cooperate as GA performs ESI data checks on GA-certified ships and also gives extra points when a ship has higher ESI scores (COGEA, 2017).

The CO₂ emission criteria weight in the CSI is 20%. They use a more specific way to incorporate CO₂ emissions. Actual emissions per ship are compared to a reference ship in the same ship category and then scores are assigned based on how the ship compares to the reference ship (ITF, 2018).

The RightShip index is scoring based on IMO’s Energy Efficiency Design Index (EEDI) or on an Existing Vessel Design Index (EVDI) to determine energy efficiency compared to the average vessel of the same size and type. It is only focused on CO₂ emission; therefore, this index is putting 100% weighting in CO₂ emissions. The measure for comparing the relative efficiency of the vessel is grams of CO₂ per tonne nautical mile. The data preferences for the RightShip index is EEDI, ship-specific data, yard data, with IHS Maritime ship-data being least preferred (ITF, 2018).

From comparing the aspects of the widely used index, some of the issues can be drawn out. First, the index does not put emphasis on GHG emissions. Port-based incentives with more focus on GHG emissions could be increased by aligning closely with actual GHG emissions from ships. GHG emission mitigation could be increase by putting more weighting factors for GHG emissions in port schemes, replace the local pollutants by GHG emissions or change the way local pollutants are embedded in the index. Thus, port-based incentives could be more effective in alleviating shipping GHG emissions. Most port-based incentives have multiple environmental goals related to local pollutants, noise, and dust. However, this is important for the ports; many of the local pollutants are already subject under regulation. Sulphur emission from shipping is under the global cap regulation. This means that the value-added of port-based incentives on mitigating sulphur emission is most likely small (ITF, 2018).
Second, for CSI although it has already come with a specific way to address CO₂, they consider EEOI as their benchmarking to differentiate ship emissions. The EEOI is considered not stable as it will be disturbed by external components like weather, ship handling, and load factor. This will also make the scoring change. For RightShips, they are only using EEDI or EVDI. They do not take the operational aspect into accounts. A problem may happen if a ship with a low EEDI is not the ship with the lowest CO₂. It may emit more CO₂ than other ships whose EEDI is higher. A low EEDI may mean an underpowered ship, which, in its attempt to maintain speed in bad weather, may emit more than a ship with a larger engine (Psaraftis, 2016).

3.5.3 Charterers/Cargo Owners

Sustainability is a term that is currently more and more related to shipping. The sustainable development term appeared in the 1980s and the 1990s sustainability notion was implicitly framed as an integrated concept, often called as the “triple bottom line” approach (Fasoulis & Rafet, 2019). The triple bottom line approach consists of 3Ps namely: People, Planet, and Profit. In shipping management, these approaches are implemented by coordinating efforts through CSR activities. It includes focusing on emissions, training, awareness, and well-being of its staff and the community and of course the success of the business itself in terms of its bottom-line profit (Armstrong & Banks, 2015).

Quantitative research has identified that there is increasing awareness and adaptation of the maritime sector to the triple bottom line approach and, subsequent, sustainability absorption under the auspices of corporate social responsibility (CSR) business model on their insight and attitudes to triple bottom line approach for tanker and bulk carrier business (Fasoulis & Rafet, 2019). It is a positive situation since adopting Triple Bottom-lines in their CSR to ensure the accountability of shipping companies is keys to promoting energy efficiency in shipping (Ölcer & Kitada, 2016).

Energy efficiency improvements are being driven by economics, compliance, and customer requirements. The third one is currently playing a huge part. The major company, mostly those listed in stock exchanges, promote the requirement for vessels chartered by them to carry their cargo following sustainability initiatives and practices as part of their recommitment to Corporate Social Responsibility (CSR) (Armstrong & Banks, 2015). They are willing to do it because there is increasing
consumer demand for ecological and fair trade for the products (Brynpolf, et al., 2016). Energy efficiency and low carbon supply chain have become increasingly more important to customers with the rising concern of climate change (Armstrong & Banks, 2015).

Several industries and customer basis initiatives make an indicator to acknowledge the energy efficiency of ships and their efforts to mitigate it (Armstrong & Banks, 2015). Initiative indices, awards, and certification from the performance are increasingly promoted by cargo owners, NGOs, and Shipping Associations. Those include Business for Social Responsibility (BSR), Clean Shipping Project, Swedish Society for Nature Conservation, Green Marine, RightShip, and Carbon War Room. The index from environmental performance in shipping is used as communication tools to inform the performance of a ship in the form of a certificate, a label, an award, or a score in a rating system (Svensson & Andersson, 2011).

Over the last decade, many sustainable shipping initiatives have come with a high-investment research and innovation category and those driven by CSR. Sustainable shipping initiatives consider as key driver to be their economic benefit, CSR and marketing, environmental protection and shipping, and international regulation with respect to compliance (Kate, Butt, Johnson, & Walsimsley, 2011).

One example driven by CSR is the Clean Shipping Project which started as a regional initiative on the Swedish west coast in 2006 with aims to increase focus on the environmental issues of shipping. Then, it evolved into a network of large cargo owners consisting of 30 cargo owners, including Volvo and H&M. With the information provided by the Clean Shipping Database, cargo owners can use the tool to choose the ship transportation based on their environmental performance. It may also provide information on the vice versa. Ship-owners can adjust the environmental requirements since the cargo owner on the network requires them to enter the ship performance data in the index (Svensson & Andersson, 2011). In other words, it may induce the ship-owners to invest and make their ships have a high environmental requirement. Even some cargo owners, such as H&M, SKF, and Akzo Nobel, provide marketing incentives for the ship-owners who participate and perform well in the index (Svensson & Andersson, 2011).
Chapter IV
Case Studies & Discussion

4.1 Case Studies

A case study about the applicability of the developed operational KPI is set up in the example of a container vessel. The container vessel is selected because it already has a fixed route and a regular time schedule. Therefore, it will give a clear example of the applicability of the developed operational KPI.

![Figure 11 OOCL Kobe (marinetraffic.com)](image)

A case study is based on OOCL Kobe (see Figure 11). It is a container ship owned by the OOCL. The ship particular (see Table 5) are obtained from the OOCL website, scheepvaartwest.be, and MAN B&W K90MC Engine Project Guide.

<table>
<thead>
<tr>
<th>Table 8.0</th>
<th>OOCL Kobe Particular Data (scheepvaartwest.be)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ship Particular Data</td>
<td></td>
</tr>
<tr>
<td>Vessel Name:</td>
<td>OOCL Kobe</td>
</tr>
<tr>
<td>Port of Registry/Flag:</td>
<td>Hong Kong, China</td>
</tr>
<tr>
<td>Official Number:</td>
<td>HK-1932</td>
</tr>
<tr>
<td>Call Sign:</td>
<td>VTCL7</td>
</tr>
<tr>
<td>IMO Number (Same as LRI Code):</td>
<td>9099808</td>
</tr>
<tr>
<td>Class Society / Number:</td>
<td>ABS / 07154602</td>
</tr>
<tr>
<td>Year Built:</td>
<td>2007</td>
</tr>
<tr>
<td>GRT:</td>
<td>40188</td>
</tr>
<tr>
<td>NRT:</td>
<td>24450</td>
</tr>
<tr>
<td>L.O.A (meters):</td>
<td>290.049</td>
</tr>
<tr>
<td>L.B.P. (meters):</td>
<td>24.8</td>
</tr>
<tr>
<td>B. M.L.D (meters):</td>
<td>23.26</td>
</tr>
<tr>
<td>D. M.L.D (meters):</td>
<td>19.3</td>
</tr>
<tr>
<td>DWT (MT):</td>
<td>50553.8</td>
</tr>
<tr>
<td>TELUs:</td>
<td>4578</td>
</tr>
<tr>
<td>Max Speed (knots):</td>
<td>24.5</td>
</tr>
<tr>
<td>Main Engine</td>
<td></td>
</tr>
<tr>
<td>Name:</td>
<td>1x Doosan/MAN-B&amp;W K90MC-C</td>
</tr>
<tr>
<td>Cylinder:</td>
<td>8-cylinder 300 x 2,300 mm</td>
</tr>
<tr>
<td>Power:</td>
<td>36,950 kW at 104 rpm</td>
</tr>
<tr>
<td>Manufacturer:</td>
<td>Doosan Engines Co. Ltd</td>
</tr>
<tr>
<td>MT SFOC (g/kWh):</td>
<td>177</td>
</tr>
<tr>
<td>Fuel Consumption (ton/day):</td>
<td>155.3069</td>
</tr>
</tbody>
</table>
Based on the ship data, hypothetical ship scoring is constructed based on the proposed operational KPI. The ship scoring will be divided into three scenarios. Scenario A without the KPI, scenario B only with the operational scoring while scenario C use management and operation. The scenarios are given in Table 9.

<table>
<thead>
<tr>
<th>Operational KPI</th>
<th>Scenario A</th>
<th>Scenario B</th>
<th>Scenario C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applied Energy Management</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Capacity Utilization</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td><strong>Max Score</strong></td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Ship Operational</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed Optimization</td>
<td>0</td>
<td>62</td>
<td>62</td>
</tr>
<tr>
<td>Voyage Optimization</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weather Routing</td>
<td>0</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Autopilot Adjustment Application</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Trim/Draft Opt.</td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Opt. Maintenance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hull Cleaning</td>
<td>0</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>Propeller Polishing</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><strong>Max Score</strong></td>
<td>0</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td><strong>Total Score</strong></td>
<td>0</td>
<td>50</td>
<td>100</td>
</tr>
</tbody>
</table>

4.2 Potential Reduction

Scenario A does not apply any measures to reduce ship air emissions; therefore, the score will be 0 and it may be considered as the scenario with bad performance.

Scenario B implements all of the containership specific operational measures which may lead to reducing fuel consumption; and then reducing ship emissions. The implementation of speed optimization by reducing the sailing speed will also reduce fuel consumption; thus reducing GHG emissions. The vessel fuel consumption is obtained by multiplying specific fuel oil consumption (SFOC) of the engine with the engine power. The engine fuel consumption at 24.5 knots is 155.3069 tons/day.

Typical fuel consumption on 2,259 container vessels shown in Figure 12, was gathered on every speed to see the effect of the speed to the fuel consumption (Nolteboom & Carliou, 2008).
Slowing down the speed from 24.5 to 22, the fuel consumption already reduces to 100 tons/day. Further reduction will also reduce fuel consumption; thus will reduce GHG emissions.

Figure 13 OOCL Kobe Route

Voyage optimization by being well informed about the weather on the sea and also choosing the optimum route will help to optimize voyage and may reduce fuel
consumption up to 6%. For container vessels, the containers will shift at each port. OOCL Kobe sails between 9 ports. Because of the cargo shifting, the vessel may trim by bow or stern. By correcting the trim, fuel consumption of the main engine can be decrease up to 4%. Keeping the hull clean and propeller from the fouling also helps to reduce resistance; and thus will reduce fuel consumption in a range up to 17% of the main engine fuel consumption and might reduce GHG emissions.

In Scenario C the vessel implemented all of the operational measures and applied the energy management system at the company level, for example ISO 50001. It also has strategies to maximize capacity utilization. A good management system means they have their crew and shore personnel training and awareness about energy efficiency. Indirectly, it may account for a 10% reduction of CO₂ emissions. They also try to maximize their capacity utilization which may account for 50% CO₂ emissions.

The reduction effect of each of the measures is not cumulative. The combination of each of the measures requires study in-depth about the relation of each measure and the actual ship performance. In this section, the potential reduction of each of the measures was implemented on the vessel. Since not adopting any measures, there is no information about the operational efficiency of Scenario A. Scenario B implements all of the operational measures; however, on the company level the energy management system and capacity utilization were not applied. Scenario C has the highest point because it implements all of the measures on operation and management. Therefore, the implementation of the operational measures in Scenario C will be much better and assured since the company is also fully aware of the energy management system and capacity utilization. The ship in Scenario C might be identified as an energy efficient and environmentally-friendly ship.
4.3 Discussion

Ship-owners or shipping companies are the subject entity regarding shipping activities. As can be seen in Figure 14, the maritime sector comprises a lot of stakeholders that revolve around shipping companies. Shipping is a service sector with a derived demand from trade, because without any trade from the sellers to the buyers, there will be no shipping (Shuo, 2019). At present, as with globalization, trade becomes more and more important, and so does the shipping activity. It also can be seen in the message from IMO Secretary-General, Kitack Lim, who stated that seafarers are the key workers, especially in time of global pandemic, whereby there is a lot of restriction around the world (IMO, 2020). It is shown that the presence of shipping companies and seafarers working for the shipping companies is essential as a service provider for trade.

Shipping is a highly capital intensive sector measured in capital required per employment created. It requires huge investments to build modern and increasingly specialized ships (Shuo, 2019). With increasing competitiveness and fluctuating market, shipping companies must have strategies to compete in the market. A survey by Global Maritime Forum from senior maritime stakeholders found that the global economic crisis will most likely impact the maritime industry along with the likelihood
of new environmental regulations over the next 10 years. Interestingly, it was also found that the score on preparedness of the maritime industry to deal with the issues is low. From the survey, the industry is the least prepared for a global economic crisis, which is also deemed as having the most impact. The preparedness for the new environmental regulation is considered low among the respondents (GMF, 2019).

As the concern for climate change is rising and also the introduction of new environmental regulation, ship-owners must adapt to the current condition to stay competitive in the market. Ship-owners should implement and invest in measures related to energy efficiency. However, several challenges hinder the implementation of energy efficiency in the ships. This challenge is usually called as energy efficiency barriers. Understanding barriers is one step so that the implementation of energy efficiency may be achieved (Öçer & Kitada, 2016).

There is a great deal of research into energy efficiency as mentioned in chapter 3. One of the research papers found that market failures correlated to the implementation and can be an explanation for the energy efficiency barriers (Rehmatulla & Smith, 2015). One of the most important market failures is information barriers. Information barriers are important in the field of energy efficiency because information related to energy use and efficiency may become public good information; however, it is typically underprovided by ordinary market activities giving rise to information barriers to achieving energy efficiency (Johnson & Andersson, Barriers to energy efficiency in shipping, 2016).

There are examples related to information barriers, such as lack of information, overload of information, inaccuracy of information, improper information, and not using the information due to misconception. These examples make the stakeholders not being able to choose the best available energy efficiency measures (Jafarzadeh & Utne, 2014). The proposed operational KPI will help ship-owners to have a goal to make their ships energy efficient. The proposed operational KPI shows the vessel score based on the operational measures implement on the ship; and thus will make it energy efficient. Together with the technical rating, such as EEDI, it will give ship-owners information on how efficient their ships are on technical and operational aspects. With the possible future emission regulations, it will act as motivation to ship-owners to have a high score by investing in energy-efficient measures. It will also induce ship-owners to adopt logistic (operational) based
measures in the short run and technological measures in the long run. Both sets of measures would result in emissions reduction (Psaraftis, 2016). If vessels have a report about the energy performance of different vessels, they compare themselves with similar vessels and try to improve (Jafarzadeh & Utne, 2014). Therefore, it will give economic benefits for them and may also reduce GHG emissions from shipping.

In the relation to contracts, between charterer and ship-owner, split incentives are likely to occur because of different types of charters (and the divided responsibility for fuel costs) existing between ship-owners and charterers (Rehmatulla & Smith, 2015). To address the split incentives, a solution called “Smart Contract” can be used. In the contract, risks and benefits are shared among the ship-owners and charterers. Contract speed choice is more flexible, and the chartering cost of vessels is closer to fuel cost; therefore, ship owners get motivated to invest in energy-efficient technologies, and operators get stimulated to run vessels in an energy-conserving manner (Jafarzadeh & Utne, 2014). With the operational KPI, it will help to address the issue by providing transparency about the capability of the vessel information in the operation aspects which can be input for the contracts.

There is also asymmetrical information when one party has information about energy-efficient measures. It may lead to adverse selection and moral hazard. Adverse selection happens when the case of asymmetrical information happens before the contracts while moral hazard happens after the contracts (Johnson & Andersson, Barriers to energy efficiency in shipping, 2016). By employing the operational KPI with the technical KPI, such as EEDI, it will give information to both parties, thus will reduce asymmetrical information on the contracts.

4.4 Other Benefits of the Potential Application

4.4.1 Application as Operational Efficiency Evaluation in Hybrid MBM

MBM in general aims to reduce CO2 emissions and change long-term behavior for ships, in investment, and fuel efficiency, with incentives for shipping companies. The fuel price including the tax on emissions, increases because MBM will make shipping companies make an effort to improve fuel efficiency and expand voyage distance. As the fuel price (including a tax on emissions) increases, CO2 emissions decrease (Tanaka & Okada, 2019). However, there may be a rebound
effect due to the effort to improving fuel efficiency, which cancels the CO₂ reduction by the increase of voyage distance to earn additional revenue. Therefore, a policy mix for inducing improvement of ship fuel efficiency and reducing CO₂ emissions is needed. (Tanaka & Okada, 2019).

As the first step of the MBM, the EU introduced EU MRV, followed by IMO with IMO DCS. The two schemes may look similar but there are some differences in the mechanism. With the absence of intention from both scheme to merges, it may lead to jeopardizing the effort GHG emissions reduction from international shipping and have the possibility to make carbon leakage. Moreover, there are several problems related to data collection, data analysis, and data verification which also leave the applicability of these two schemes toward MBM formulation.

Several mechanisms on the MBM proposals include a hybrid proposal introducing a more practical mechanism that can be applied for shipping to be more efficient and, eventually, will reduce GHG emissions. However, there is an absence of operational efficiency evaluation to assess ship operational performance. The developed operational KPI can be used to solve these issues. The developed operational KPI will assess the ship performance based on the operational strategy implemented on the ship. Together with the technical evaluator, such as EEDI, the operational KPI will give full information about the ship’s performance on the technical aspects as well as operational aspects.

By introducing the application of the developed operational KPI on the MBM, it will also boost the MBM function effectively. With the performance evaluation in technical and operational aspects under MBM, regulations can be made to distinguish between efficient and less-efficient ships related to environmental performance.

4.4.2 Port Incentives

As mention before in the previous chapter, financial incentives may be more effective in inducing ship owners to invest and implement ship emissions in ports and voyages. From the existing index used in ports such as ESI, CSI, Green Award, and RightShip, the weight for the GHG emissions is deficient and there is lack of operational evaluation, which serves as challenges in determining effective indices for port incentives.
The proposed operational KPI focuses on the operational measures to reduce GHG emissions on the operational side. Therefore, it will give information about the ship's performance related to operational measures.

Applying operational measurements is considered to be effective instruments. One example, was shown by the ports of Los Angeles and Long Beach (POLB) on vessel speed reduction scheme. It aims to reduce emissions from ships by slowing their speeds as they approach or depart from the port. According to the Port of Long Beach Compliance Report for 2016, the participation from shipping companies has been very high. Over 96% at 20 nautical miles and over 88% at 40 nautical miles. In 2008, it was estimated that the program successfully reduced CO2 equivalent emissions by 26,000 tonnes. The program also reduced NOx, SOx, and PM emissions by 678, 453, and 60 tonnes respectively (ITF, 2018). It was also shown that the scheme provided has a positive effect on compliance to the bulk, containership, general cargo, tanker, and mixed-cargo vessel operators, although the effects vary greatly by operator type (Ahl, Frey, & Steimetz, 2018).

Speed optimization is one of the operational measures stipulated in the proposed Operational KPI. Therefore, ships which has a high score in the developed operational KPI will benefit from port incentives by reducing GHG emissions effectively.

4.4.3 Charterers/Cargo Owners

As with the rising concern of environmental issues, consumers demand to be fully informed on how environmentally friendly their carrier is. Therefore, informational KPI can help them to see their ship environmental level. In addition to the technical index, such as EEDI, applying operational KPI will give vessel information on technical and operational performance. Therefore, it will also give the vessel benefits to the companies and vessel promotional image.
Chapter V

Conclusion and Further Study

6.1 Conclusion

Shipping which acts as the main driver in maritime transport is the most efficient transport mode and 4/5 cargo trade is carried through the ocean (Shuo, 2019). Shipping still relies on fossil fuels; therefore, it is considered as one of the contributors to GHG emissions. In 2012, shipping GHG emissions was 977 million tonnes CO2e; then it increased to 1,076 million tonnes CO2e in 2018. The share of shipping emissions among global anthropogenic emissions also rose from 2.76% in 2012 to 2.89% in 2018 (Faber, et al., 2020).

As with the climate change, effects are more and more felt. While the trend of emission keeps rising, the shipping industries need to produce regulations to effectively reduce GHG emissions. IMO as the highest regime in international shipping has devised policies to reduce GHG emissions. The track of the energy policies can be divided into two parts. Part I are EEDI and SEEMP and part II is MBM (Psaraftis, 2019). In the process, there are several challenges that hinder the finality to reduce GHG emissions from international shipping. In part I, SEEMP has many deficiencies which makes it ineffective to promote energy-efficient ship operations. It has become just a matter of compliance in the shipping operation with not much real effect. In part II the MBM discussion is stalled then the discussion was shifted to fuel consumption monitoring, reporting, and verification as the first step of MBM. However, some issues related to data collection, data analyzing, and data verification challenge the implementation of the scheme. Moreover, there seems to be a clash between IMO’s DCS and EU’s MRV. The two schemes on collecting ship fuel oil consumption data have a similar objective but different mechanisms. It creates an administrative burden for ship-owners and with no intention of merging the two schemes, so the efforts to reduce emissions from international shipping could be jeopardized. Recent developments show that the path to significant CO2 reduction faces difficulties and the main obstacles are neither technical nor economic, but political (Psaraftis, 2019). A more practical way to reduce GHG emissions from international shipping is needed.

An alternative Operational KPI proposed and developed in this research could be a way forward to introduce a more practical way to show and gain more effective
results to reduce international shipping emissions. Ship rating may become an alternative because it induces shipping companies and ship-owners to adopt energy-efficient measures to reduce emissions from shipping. In the technical aspect, there is EEDI while in the operational aspect there is no evaluator that can distinguish ship performance. The proposed Operational KPI might be an alternative to fill in the gap for the operational evaluator. While most of the ship rating tools focus on the emission caused by ships, the proposed operational KPI emphasizes efforts and measures to reduce fuel consumption on ships; and thus will has a potential to GHG emissions effectively. The developed operational KPI can be applied on any kind of ship; however, the scoring needs to be tailored based on the ship type.

The research about combinations on current technical and operational measures which result in 75% emissions reduction by 2050 is available (Bouman, Linstad, Riaalland, & Stromman, 2017); however, there are energy-efficiency gaps that hinder the implementation of the measures by the ship-owners. Due to focusing more on the efforts, the proposed operational KPI could be bridging the energy-efficiency gaps. Together with the technical evaluator, such as EEDI, the proposed Operational KPI might be the way to promoting energy-efficiency practices; and thus will effectively reduce GHG emissions from international shipping. The case study provided, a ship with a high score with the proposed Operational KPI might show its potential to reduce GHG emissions. Therefore, it will come with benefits for the ship and the companies. The benefits could be shown from the possible application of the proposed Operational KPI.

The possible application of the proposed Operational KPI can be divided into four perspectives. For ship-owners, the use of the hybrid MBM mechanism, for port incentives, and for charterers/cargo owners.

For ship-owners, it is straightforward as it may become the goal of adopting measures to fuel consumption; thus reducing GHG emissions. In the Hybrid MBM mechanism, together with EEDI, it may become a ship evaluator to impose further regulation, for example, bunker levy. The proposed Operational KPI could be used by ports to come with port incentives. In this case, it will also motivate ship-owners to implement and have a high score on the KPI due to the financial incentives provided by ports. For charterers and cargo owners, the proposed Operational KPI may
become the standard for their products as the awareness of the sustainability concept is becoming more and more stringent.

The benefits from the possible application which may come from the Hybrid MBM mechanism, port incentives, and charterer’s requirements, ship-owners might compete to achieving a high score on the KPI by implementing measures and make their ships more energy efficient and environmentally friendly. Finally, it might effectively reduce the emissions that come from international shipping.

6.2 Further Research

The proposed Operational KPI seems to be beneficial and may have a lot of application. However, further research is needed to investigate more clearly about the effectiveness of this KPI. Further research which may be developed to enhance the effectiveness of the KPI is:

- Investigating the implementation on different ship types because each ship has its own characteristic and market constraint.
- Investigating the degree of implementation on every measures so that it will full reflect ship performance.
- Developing a framework to implement the operational KPI which include verification and audit scheme.
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WPCI. (2010). *Environmental Ship Index (ESI)*. WPCI.