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Research Paper

Strategy For the Shipping Decarbonisation Using Marine Diesel Oil

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Abstract

Climate change has become a global problem. Transportation is one of the contributors to the problem of increasing carbon emissions. The world of shipping, as the most significant mode of transportation of goods worldwide, contributes to increasing carbon emissions. Greenhouse Gas Emission has led IMO to participate in implementing policies related to decarbonization in the maritime world, which began in 2020. This research aims to understand the use of Marine Diesel Oil as one of the strategies implemented to reduce the impact of carbon emissions. This study uses a qualitative research methodology using primary data based on observations on board and secondary data from reputable international journals. In addition, data analysis uses the SWOT matrix. The results of this study are to determine the strengths and weaknesses of using MDO, as well as opportunities and threats to using MDO in Emission Control Areas. The hope is that ECA can be expanded, especially in world shipping lanes, to minimize the impact of carbon emissions. In addition, more in-depth research on decarbonization in the maritime industry and the port area can be carried out.

Keywords: *Decarbonization; MDO; ECA; Climate Change; Shipping*

INTRODUCTION

Transforming the transport sector, specifically the global maritime shipping industry, into a sustainable and low-carbon economy is a prominent challenge in the twenty-first century. Maritime transportation serves as the cornerstone of international commerce and is the most reliable method for the transportation of products. Maritime channels are responsible for transporting over 80% of the global cargo volume and more than 70% of the value of international trade. The maritime transport industry, reliant on liquid fuels, constitutes a significant consumer of petroleum-derived petrol. In contrast to alternative refined fuels, heavy fuel oil (HFO) is predominantly utilized as the principal energy source in maritime transportation due to its composition as a by-product of the oil refining procedure, which includes undesirable contaminants. Other maritime fuel types commonly used in the industry include marine petrol oil (MGO), marine diesel oil (MDO), and intermediate fuels.

The maritime industry, at a global scale, is responsible for approximately 13% of the total sulfur oxide (SOx) emissions created by human activities, as well as 2.6% of all carbon dioxide (CO2) emissions resulting from human activities. The maritime industry encounters several challenges concerning emission regulations, significantly contributing to pollutant emissions. By the regulations set forth by the International Maritime Organisation (IMO), the global marine fuel sector has recently reduced the sulfur content of marine gasoline, decreasing it from 3.5% m/m (mass by mass) to a mere 0.5% m/m. This adjustment, scheduled to be enforced on January 1, 2020, has been undertaken to ensure compliance with the emission limit established by the IMO (Tan et al., 2022).

The development of the Emission Control Area (ECA) was driven by the need to mitigate air pollution resulting from ship emissions, specifically Sulphur Oxides (SOx) and Nitrogen Oxides (NOx). These pollutants have been identified as adversely impacting air quality and human health.

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The primary aim of this study is to assess the efficacy of employing Marine Diesel Oil as a decarbonization strategy within the maritime transportation sector.

LITERATURE REVIEW

Numerous scientific findings have demonstrated that there has been a significant change in the climate. These climate problems have been discussed for a very long time. The Earth's temperature has risen by around 0.8°C over the past century, according to Assessment Reports 5 (AR5) of the Intergovernmental Panel on Climate Change (IPCC) (Rajamanickam et al., 2022). According to the report, global temperatures are predicted to rise by 1.8 to 4°C by the end of 2100 compared to the mean temperature between 1980 and 1999. This increase in world temperature is similar to 2.5–4.7°C even when it is further compared to the pre-industrial era (1750).

It illustrates that Earth's temperature has increased due to global warming. Heat waves and severe downpours have increased in frequency and intensity in many places, along with Earth's temperature. *Global warming* is the term used to describe the gradual increase in the temperature of the Earth's atmosphere, which is often attributed to the greenhouse effect caused by rising levels of carbon dioxide, chlorofluorocarbons, and other pollutants.

An essential first step in comprehending the current climate emergency is to be aware of the disastrous effects of climate change on people and natural ecosystems, as well as the dangers and vulnerabilities (Fawzy, 2020). The most recent reports from the United Nations Climate Change Secretariat (UNCCS) describe changes in climate variables like air temperature, rainfall, sea level rise, ocean acidification, and extreme weather. Landslides, heatwaves, wildfires, storms, flooding, and surges are a few examples of climate dangers (Irena et al., 2021). There were 315 natural catastrophe incidents globally in 2018, most of which were climate-related, according to data from the Centre for Research on the Epidemiology of Disasters (CRED). One hundred twenty-seven floods, 16 droughts, 26 highly high temperatures, 13 landslides, 95 storms, and ten wildfires occurred.

Natural disasters affected 68.5 million people that year, causing 94% of the total damage from floods, storms, and droughts. Storms ($70.8 billion), floods ($19.7 billion), wildfires ($22.8 billion), and droughts ($9.7 billion) accounted for the majority of the costs, or over 93% of the total, of the $131.7 billion in economic losses from natural disasters in 2018. Data on disaster patterns over the last ten years is also provided by CRED, except for wildfires, demonstrating an almost universal rise in average annual occurrences. It is important to note that the economic losses brought on by wildfires in 2018 alone were approximately equal to the sum of the losses brought on by wildfires during the previous ten years (CRED 2019). Wildfires are also a significant contributor to carbon dioxide (CO_2) emissions. Wildfires are a regular occurrence in the environment. However, it is evident that human-produced emissions directly interfere with and exacerbate the effects of natural emissions. The rising frequency of natural disasters worldwide is primarily due to climate change brought on by human activity.

Using fewer private cars for daily commuting and more public transit is one of the actions to combat the effects of climate change. Using MDO (Marine Diesel Oil), which has a higher sulfur content and hence produces more CO_2 emissions, is preferable to using low-sulfur fuel oil in the maritime sector. Decarbonization is the term used frequently to describe this process. Decarbonization is the process of lowering or removing carbon dioxide (CO_2) emissions from various human activities, especially those related to burning fossil fuels, including coal, oil, and natural gas. Decarbonization's primary goal is to reduce the amount of greenhouse gases in the atmosphere, which will lessen the effects of global climate change (Alzahrani et al., 2021).

As part of implementing the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, ports must address their greenhouse gas (GHG) emissions, including those from the shipping industry (Romano and Yang, 2021). As a result, there are several GHG reduction regulations relating to shipping that the general public and port authorities should consider while putting them into practice.

This legislation covers international, supranational, regional, national, and municipal levels. Port authorities carry out these obligations as regulatory bodies by passing pertinent regulations, making them enforceable, and monitoring compliance (Alamoush et al., 2022).

There are numerous international rules in place to reduce emissions from ships. They begin with Articles 190, 194, 211 (3), 212 (1), and 222 of the United Nations Convention on the Law of the Sea (UNCLOS), which call for and allow parties the power to enact laws and regulations to lessen maritime pollution. While port nations enforce these rules under national marine authorities, the International Maritime Organization (IMO) regulates shipping emissions, including GHGs (Pal et al., 2023). The IMO MARPOL regulations, for instance, are implemented by port authorities (Notteboom et al., 2023).

All new vessels must be built and designed per Regulations 20 and 21 of MARPOL Annex VI, Chapter 4 - Annex VI, "Regulations on energy efficiency for ships," which integrate the Energy Efficiency Design Index (EEDI) (Animah et al., 2018). The Ship Energy Efficiency Management Plan (SEEMP), necessary for all contemporary ships, is also included in the Annex. The Energy Efficiency Operator Indicator (EEOI), a voluntarily agreed-upon operating baseline for CO2 emissions, is contained to ensure SEEMP compliance. Port authorities verify the international energy efficiency certifications (IEEC) issued to ships by flag nations for those exceeding 400 gross tonnes.

RESEARCH METHOD

The methodology used in this research is qualitative—the data was collected by observation in the Yang Tze River while on board. In this research, the researcher became an observer and directly observed the fuel replacement incident when entering the ECA area. The research team also conducted interviews and discussions with the ship captain, first engineer, and third engineer.

To build a comprehensive overview of the literature, we draw on the many published reviews of decarbonization with widely varying focuses and periods of interest, primarily from reputable journals such as Science Direct, Sustainability, Springer, Sage, and Nature. (Emodi et al., 2022) The steps used in journal analysis include the following:

1. Defining the subject
2. Using a keyword search string to find relevant studies
3. Reading articles in-depth to choose studies for the review
4. Extracting data from the retrieved studies
5. Analyzing, fine-tuning, and summarising findings for publication

The data analysis technique used by the researcher is the use of SWOT analysis. The primary goals of SWOT (which were later renamed as Strengths, Weaknesses, Opportunities, and Threats, or SWOT) were to handle the issues of preserving contentment, opening Opportunities, fixing errors, or resisting Threats (Puyt et al., 2023)

FINDINGS AND DISCUSSION

In 2019, China implemented the use of MDO fuel regulations, aiming to reduce pollution in its region. The Yangtze River is a significant river in China with the world's highest ship traffic. Hence, every vessel passing through the river is required to adhere to the ECA (Emission Control Area) regulations (Zhou et al., 2023). LSFO and MDO fuels have distinct characteristics and uses. LSFO is thick at room temperature of around 30°C and needs to be heated before use, while MDO at room temperature of 30°C is already in liquid form. Certainly, these differences in properties greatly affect ship engines in their usage.

Especially in the China Yangtze River area, there is an extreme temperature difference within a year, where during the summer, the river water temperature can reach up to 30°C. In contrast, during the winter, the water temperature can be 0 degrees Celsius. These temperature variations have varying impacts on the treatment of both MDO and LSFO fuels.

LSFO (Low-Sulfur Fuel Oil) fuel has a low sulfur content. LSFO is one of the types of fuel used in the shipping industry to meet the stringent environmental regulatory requirements regarding Sulfur Dioxide (SOx) Emissions set by the International Maritime Organization (IMO) (Rao et al., 2023). The contents are as follows:

1. Hydrocarbons

LSFO fuel consists of hydrocarbons, such as alkanes, alkyl benzene, and other hydrocarbon compounds. These hydrocarbons are the main components that provide energy when burned and are used to drive engines.

2. Sulfur

Although LSFO fuel has a low sulfur content, it still contains a small amount of sulfur. International regulations set a maximum limit for sulfur in LSFO fuel, such as 0.5% outside the Emission Control Area (ECA). However, some manufacturers may produce fuel with lower sulfur content.

3. Nitrogen

LSFO fuels may also contain nitrogen, although to a lesser extent than fuels with higher sulfur content. Nitrogen Dioxide (NOx) emissions must also be managed and reduced following applicable regulations.

4. Oxygen

Occasionally, LSFO fuel may also contain oxygen in the form of organic compounds such as oxygenates or certain methyl esters. Some of these compounds can be added as additives to improve the combustion properties or stability of the fuel.

It is important to note that the specifications and composition of LSFO fuel may vary depending on the manufacturer and where it is used. Fuel manufacturers will ensure that their products comply with applicable regulatory requirements and standards, including sulfur content limits set by the IMO and other local regulations.

Table 1. The Specification of LSFO

Number	Characteristics	Unit	Min Limit	Max Limit	Test Method
1	Specific Gravity at 15°C	kg/m^3	-	991	ASTM D1298
2	Kinematic Viscosity at 50°C	mm^2/s	-	380	ASTM D445
3	Sulphur Content	% m/m	-	00.05	ASTM D1552 / D2622 / D4294
4	Pour Point	°C	-	39	ASTM D97
5	Flash Point	°C	60	-	ASTM D93
6	Total Acid Number	mg.KOH/g	-	02.05	ASTM D664
7	Carbon Residue	% m/m	-	18	ASTM D189
8	Ash Content	% m/m	-	00.01	ASTM D482
9	Total Sediment	% m/m	-	00.01	ASTM D473
10	Water Content	% v/v	-	00.05	ASTM D95
11	Vanadium	mg/kg	-	350	ASTM D5708 / IP 501 / IP 470
12	Alumunium + Silicon	mg/kg	-	80	ASTM D5184 / D5185 / IP 501 / IP 470
13	Used Lubricating Oil	-	-	Free from Used Lubricating Oil (ULO)	ASTM D5185 / IP 501 / IP 470 / IP 500

Note : *) In the event of a misunderstanding, measurements are taken to establish that the following conditions are met :

1. Calcium < 30 mg/kg
2. Zinc < 15 mg/kg or phosphor < 15 mg/kg

Reference: SK Dirjen Migas No. 179.K/10/DJM.S/2019 September 10, 2019, regarding fuel standards and quality specifications.

MDO fuel (Marine Diesel Oil) is a type of fuel used in shipping systems. MDO is commonly used to ship diesel engines, especially for medium to high-speed ones. Due to the International Maritime Organization's new SOx emission rules, MDO was also essential for the bunker fuel business (Li et al., 2021). The composition is as follows:

1. Hydrocarbons

MDO fuel consists of a mixture of hydrocarbons, mainly the lighter fractions produced by refining petroleum. Hydrocarbons include alkyl line systems and other hydrocarbon compounds. These hydrocarbons provide the system when burned and are used to drive engines.

2. Sulfur

MDO fuel contains sulfur, although at a lower level than heavy fuels such as heavy fuel oil (HFO). Sulfur content varies depending on the specifications and regulations that apply. However, MDO fuel generally has a lower sulfur content than HFO.

3. Nitrogen

MDO fuel also contains nitrogen in varying amounts. Nitrogen Oxide (NOx) emissions must also be managed and reduced by applicable environmental regulations.

4. Additives and Stabilizers

Some MDO fuel manufacturers may add additives and stabilizers to improve combustion properties, stability, and corrosion protection. These additives can help optimize fuel performance and protect the system from damage.

Table 2. The Specification of MDO

Number	Characteristics	Unit	Min Limit	Max Limit	Test Method
1	Specific Gravity at 15°C	kg/m^3	850	900	ASTM D1298 / ASTM D4052
2	Kinematic Viscosity at 40°C	mm^2/s	03.05	11.00	ASTM D445
3	Sulphur Content	% m/m	-	01.05	ASTM D1552 / D2622 / D4294
4	Pour Point	°C	-	18	ASTM D97
5	Flash Point	°C	63	-	ASTM D93
6	Setana Index	-	35	45	ASTM D4737
7	Carbon Residue	% m/m	-	00.05	ASTM D189 / D4530
8	Ash Content	% m/m	-	00.02	ASTM D482
9	Total Sediment	% m/m	-	00.02	ASTM D473
10	Water Content	% v/v	-	00.25	ASTM D95
11	Vanadium Content	mg/kg	-	100	ASTM D5708 / IP 501 / IP 470
12	Alumunium + Silicon	mg/kg	-	25	ASTM D5184 / D5185 / IP 501 / IP 470
13	Color	No. ASTM	6	-	ASTM D1500

In China, a significant ECA area is the East China Sea ECA, which encompasses the waters around the eastern coast of China and includes several major ports such as Shanghai and Ningbo. Within this ECA area, ships are required to adhere to stricter emission limits and use fuels with very low Sulphur content, such as fuels with a maximum sulphur content of 0.5% m/m.

Figure 1. Map Emission Control Area in Yangtze River

The implementation of decarbonization efforts, such as the ECA, in the maritime sector of the Yangtze River encompasses measures to reduce greenhouse gas emissions and other pollutants generated by ships operating in the river's vicinity. An ECA is a geographical area where stringent regulations are applied to ship emissions to protect the environment and human health. Here are several potential restrictions that could be imposed in the decarbonization efforts of the Yangtze River:

1. Stringent Emission Standards: The government may establish stricter emission standards for ships operating in the Yangtze River. It could involve limitations on greenhouse gas emissions like CO_2, CH_4, and N_2O, as well as other pollutants such as sulfur dioxide (SO_x) and nitrogen oxides (NO_x). Ships must adhere to these emission limits by adopting cleaner and more environmentally friendly technologies.
2. Clean Fuel Usage: Ships in the Yangtze River ECA might be required to use cleaner fuels, such as low-sulfur fuels or even alternative fuels like Liquefied Natural Gas (LNG), that produce lower emissions compared to conventional fossil fuels.
3. Low-Emission Technologies: Ships operating in the Yangtze River could be mandated to install low-emission technology equipment, such as exhaust gas cleaning systems (scrubbers) to reduce sulfur emissions and Selective Catalytic Reduction (SCR) systems to lower nitrogen emissions.
4. Speed Limitations: The government may impose speed restrictions on ship operations within the ECA to reduce emissions. These limitations can help decrease fuel consumption and emissions.
5. Support for Green Technologies: The government can provide incentives or financial support for ships that adopt green and environmentally friendly technologies. It might include tax incentives or subsidies for investments in decarbonization technologies.

Table 3. The SWOT Matrix

Strength (Internal Factor)	Weakness (Internal Factor)	Opportunity (External factor)	Threats (External factor)
By using MDO with lower sulfur content, vessels can help reduce the contribution to SOx emissions in the ECA area.	MDO fuel is usually more expensive than other fuel types, such as Heavy Fuel Oil.	The use of MDO that complies with ECA regulations demonstrates the shipping industry's commitment to compliance with environmental laws and regulations.	The availability of MDOs in ECA areas needs attention. The international shipping industry must ensure adequate supplies to traverse these areas.
MDOs could force international shipping companies to comply with stricter emission regulations in ECA areas, such as those implemented on the Yangtze River.	Transferring fuel between LSFO to MDO takes time because it has different liquid properties. LSFO requires a temperature of 70oC to be ready for use, while MDO is only 30oC ready to use.	MDO was used to implement decarbonization in the international shipping industry.	Requires strong commitment among various countries in implementing ECA policy.
Reducing emissions of exhaust gases and other pollutant substances through MDO can contribute to improving air quality around the Yangtze River and positively impact the environment and the health of local residents.	Spare parts wear out faster due to frequent temperature changes from the hot LSFO temperature to the much cooler MDO temperature. The fuels need to follow the specifications for the type of ship engine.	Ships that run on MDO fuel and contribute to environmental protection tend to earn better sustainability and corporate social responsibility reputation.	

CONCLUSIONS

Based on the SWOT analysis, the conclusions obtained in this study are that MDO can reduce the contribution to exhaust emissions, especially in the international shipping industry. In addition, the weakness of implementing MDO on ECA is that MDO is more expensive than other fuel types. Then, the opportunity to increase the success of ship decarbonization is strong policy support. Then, the potential threat that complicates the success of the implementation of ship decarbonization is if the availability of MDO needs to be improved, especially in ECA.

LIMITATION & FURTHER RESEARCH

Further research that can be carried out includes research related to decarbonization strategies in the shipping industry with other methods or decarbonization in the port area.

REFERENCES

Alamoush, A.S., Ölçer, A.I., Ballini, F., 2022. Ports' role in shipping decarbonisation: A common port incentive scheme for shipping greenhouse gas emissions reduction. Clean. Logist. Supply Chain 3, 100021. https://doi.org/10.1016/j.clscn.2021.100021

Alzahrani, A., Petri, I., Rezgui, Y., Ghoroghi, A., 2021. Decarbonisation of seaports: A review and directions for future research. Energy Strategy Rev. 38, 100727. https://doi.org/10.1016/j.esr.2021.100727

Animah, I., Addy-Lamptey, A., Korsah, F., Sackey, J.S., 2018. Compliance with MARPOL Annex VI regulation 14 by ships in the Gulf of Guinea sub-region: Issues, challenges and opportunities. Transp. Res. Part Transp. Environ. 62, 441–455. https://doi.org/10.1016/j.trd.2018.03.020

Emodi, N.V., Okereke, C., Abam, F.I., Diemuodeke, O.E., Owebor, K., Nnamani, U.A., 2022. Transport sector decarbonisation in the Global South: A systematic literature review. Energy Strategy Rev. 43, 100925. https://doi.org/10.1016/j.esr.2022.100925

Fawzy, S., 2020. Strategies for mitigation of climate change: a review. Environ. Chem. Lett.

Irena, K., Ernst, W., Alexandros, C.G., 2021. The cost-effectiveness of CO2 mitigation measures for the decarbonisation of shipping. The case study of a globally operating ship-management company. J. Clean. Prod. 316, 128094. https://doi.org/10.1016/j.jclepro.2021.128094

Li, Y., He, P., Li, Z., Xu, H., Jarvis, J., Meng, S., Song, H., 2021. Catalytic desulfurization of marine gas oil and marine diesel oil under methane environment. Fuel 289, 119864. https://doi.org/10.1016/j.fuel.2020.119864

Notteboom, T., Satta, G., Persico, L., Vottero, B., Rossi, A., 2023. Operational productivity and financial performance of pure transhipment hubs versus gateway terminals: An empirical investigation on Italian container ports. Res. Transp. Bus. Manag. 47, 100967. https://doi.org/10.1016/j.rtbm.2023.100967

Pal, P., Gopal, P.R.C., Ramkumar, M., 2023. Impact of transportation on climate change: An ecological modernization theoretical perspective. Transp. Policy 130, 167–183. https://doi.org/10.1016/j.tranpol.2022.11.008

Puyt, R.W., Lie, F.B., Wilderom, C.P.M., 2023. The origins of SWOT analysis. Long Range Plann. 56, 102304. https://doi.org/10.1016/j.lrp.2023.102304

Rajamanickam, K., Leela, V., Suganya, G., Basha, S.H., Parthiban, M., Visha, P., Elango, A., 2022. Thermal cum lipopolysaccharide-induced stress challenge downregulates functional response of bovine monocyte-derived macrophages. J. Therm. Biol. 108, 103301. https://doi.org/10.1016/j.jtherbio.2022.103301

Rao, X., Sheng, C., Hou, X., Wei, Y., Dai, L., 2023. Preparation and properties of graphene composite lubricants additive used for cylinder liner in marine diesel burning low sulfur fuel oil. Wear 528–529, 204994. https://doi.org/10.1016/j.wear.2023.204994

Romano, A., Yang, Z., 2021. Decarbonisation of shipping: A state of the art survey for 2000–2020. Ocean Coast. Manag. 214, 105936. https://doi.org/10.1016/j.ocecoaman.2021.105936

Tan, E.C.D., Harris, K., Tifft, S.M., Steward, D., Kinchin, C., Thompson, T.N., 2022. Adoption of biofuels for marine shipping decarbonization: A long-term price and scalability assessment. Biofuels Bioprod. Biorefining 16, 942–961. https://doi.org/10.1002/bbb.2350

Zhou, F., Wang, Y., Liu, J., Yang, X., Hu, Z., Guo, T., Zhu, H., Han, Y., 2023. Influence of ship emission control area policy on air quality at Shanghai Port—local and regional perspectives. Ecol. Indic. 155, 110951. https://doi.org/10.1016/j.ecolind.2023.110951