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ORIGINAL

# Maritime pollution mitigation strategy for the sustainability of international trade

# Estrategia para la mitigación de la contaminación marítima para la sostenibilidad del comercio internacional

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**ABSTRACT**

The objective of this research article is to seek strategies that can reduce environmental pollution that affects the climate factor, being oil tankers the ones that emit the most carbon dioxide emissions globally, that is why proposals were established by entities such as the (UNFCCC) and the (IMO) that seek the reduction of GHG emissions by establishing efficient projects that seek to reduce CO2 emissions by 2050, applying the current ISO 50,001 regulations that seek energy efficiency and favorable for the climate factor. That is why it is sought through renewable sources, as opposed to traditional fossil fuels. The main objective of green fuels is to reduce dependence on fossil fuels and mitigate the environmental impacts associated with their use, such as greenhouse gas emissions and air pollution. Green fuels seek to promote the transition to a more sustainable, low-carbon economy, a clear example being the strategies developed by the fuzzy ahp application that applies a hybrid vikor methodology to investigate the strategy to reduce air pollution from diesel-powered ships globally.

**Keywords:** Pollution; Ship; Carbon Dioxide; Emissions; Sustainavle.

**RESUMEN**

El objetivo de este artículo de investigación es buscar estrategias que puedan reducir la contaminación ambiental que afecta el factor climático siendo los buques los que mayor emisión de dióxido de carbono emiten a nivel global es por eso que se establecieron propuestas por entidades como la (CMNUCC) y la (OMI) buscan la reducción de la emisión de los GEI estableciendo proyectos eficientes que buscan para el 2050 reducir la emisión del co2 aplicando las normativas vigentes ISO 50,001 que busca eficiencia energética y favorable para el factor climático. Es por eso que se busca a través de fuentes renovables, en contraposición a los combustibles fósiles tradicionales. El objetivo principal de los combustibles verdes es reducir la dependencia de los combustibles fósiles y mitigar los impactos ambientales asociados con su uso, como las emisiones de gases de efecto invernadero y la contaminación del aire. Los combustibles verdes buscan promover la transición hacia una economía más sostenible y baja en carbono un claro ejemplo son las estrategias elaboradas por la aplicación de fuzzy ahp que aplica una metodología híbrida vikor para investigar la estrategia para reducir la contaminación del aire procedente de los buques con propulsión Diésel a nivel mundial.

**Palabras clave:** Contaminación; Buque; Dióxido de Carbono; Emisiones; Sostenibilidad.

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## INTRODUCTION

This research article compiles several aspects, figures, and factors influencing how international maritime trade logistics management affects the environment.

Planned global operations and explicitly coordinated processes may deliver products to buyers, but they also account for up to 75 % of organisations' carbon footprint, which is serious for the climate. These hosts limited the meetings necessary to resolve the issue from a manageability perspective, giving rise to terms such as eco-coordinated operations, sustainable strategies, coordinated green operations, clean ports, and reverse logistics.[1] This implies that Latin American commercial organisations must be competitive. The results were obtained through a subjective methodology and graphical exploration, given the logical articles that have investigated organizations' experience in using opposing strategies.[2] Currently, the following is considered of utmost importance: the relationship with the climate. This connection is discussed briefly in all countries worldwide, since, unusually or directly, everyone should join in moderating the severe impacts of their activities.[3]

On the other hand, innovation has progressed with systems that favour the reduction of carbon dioxide. Along these lines, progress has been made with changes and transformations in the fundamental means used in ocean port activities. As a result, this global exchange has progressed in line with the ecological approaches put forward by nations to be, to a certain extent or absolutely, harmless to the ecosystem.

However, it should be borne in mind that they influence the climate. Some causes are ocean dumping, which addresses a global pollution problem, showing little commitment to the marine biological system and a lack of impressive skill in the execution of tasks. On the other hand, the aim is to raise awareness among users of the numerous measures and methods adopted to prevent these disasters and end this environmental problem that draws so much attention to the image of the marine world.

## METHOD

This article uses qualitative research methodology and reviews primary sources such as articles, research papers, and theses from national and international universities, such as the University of León, Libre, and websites such as the International Maritime Organisation (IMO). It delves into each source to establish search results that help identify the causes of marine pollution as a consequence of international trade.

Writing plan.

### Global Maritime Trade Dynamics

In recent years, countries have become increasingly open to international trade, which has led to closer ties between nations. This makes it difficult for a country to completely isolate itself from the economic activities of other countries without affecting its growth and economic development. The economic progress of many countries has been driven by their willingness to open their borders and markets to foreign investment and trade.[4]

Much of this economy is significantly influenced by maritime trade dynamics. Ships loaded with all kinds of products, from food to manufactured goods, are transported across the oceans, arriving at different ports around the world, making it an important component and the main point of exchange of goods. This is due to factors such as trade agreements, product demand, and changes in government policy. This dynamic has also been influenced by the development and advancement of new technologies and port infrastructure improvements, reducing transport costs and increasing trade volumes. China has invested the most in maritime connections, whose intercontinental routes depart from the 'Belt and Road' and the 'String of Pearls' to ensure the commercial and logistical sustainability of the ports connecting Asia and Africa. Moreover, Europe is bringing its energy sources closer together more strategically, while straits and canals continue to facilitate the transport of goods around the world.[5]

### Polluting agents

Ships are the most widely used means of transport in international trade. Their cost, size, stability, and ability to cover any part of the world, among other factors, make them the most attractive option. However, this does not prevent their negative impact on the environment, which translates into the concentration of atmospheric, marine, and coastal pollution.

*Exhaust emissions*

Carbon dioxide emissions: Ships mainly burn fossil fuels such as diesel or oil to generate energy and power the ship's engine. During the ignition cycle, carbon dioxide, other gases, and dirty particles are discharged. CO2 emissions depend on the type and amount of fuel used, as well as the vessel's engine power and operating conditions. Ships produce a large amount of carbon dioxide emissions, which account for a large proportion of emissions from all modern vehicles.

Nitrogen oxides (NOx): This term refers to the combination of nitrogen and oxygen created as a by-product of fuel consumption in the air. The gases released are nitrogen oxide (NO), nitrogen dioxide (NO2), and smaller amounts of other complex synthetics, including nitrogen oxides. This causes the development of photochemical exhaust clouds (air pollution), raising ozone (O3) to higher levels, where, if this gas is found in the lower atmosphere, it is a substance harmful to ozone.[6]

N2O) and nitrates (NO3): the amount released is directly related to the ignition temperature; the higher the maximum temperature, the higher the level created. Although these gases are also present in the exhaust gases of heaters, lower fire temperatures result in lower rates. The high temperatures and stresses in diesel engine chambers combine to create moderately high levels of these harmful gases. These gases combine with water and oxygen in the environment to form corrosive nitric and corrosive nitrous, which are incredibly harmful.

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Sulphur oxides (SOx): These are a group of gases formed from sulphur trioxide (SO3) and sulphur dioxide (SO2). The best known is SO2, as SO3 is only a transition in the composition of sulphuric acid (H2SO4). Sulfur dioxide is an odorless, non-combustible gas with a strong odor. Its half-life in the environment is short, two to four days, but it can travel long distances with the breeze and be inhaled deeply into people's lungs, increasing weakness and sudden death from heart and lung diseases.[7]

*Underwater noise*

This has important consequences for marine ecosystems and animals that use sound to communicate, navigate, and find food. The leading cause of underwater noise from large ships at sea is cavitation caused by propellers, as their rapid rotation creates bubbles that burst violently in the process, generating loud noises. However, the level and intensity of the underwater noise generated will depend on the size, load, speed, engine type, and mode of operation of the vessel. Thousands of commercial ships, cruise ships, oil tankers, etc., generate noise in the marine environment.[8]

**Analysis of pollution by ships**

Almost 90 % of global trade is carried out on board 90 000 ships. In addition, like any other method of transport that uses petroleum products, shipping also generates substances that are harmful to the ozone layer and contribute to environmental change and ocean acidification. The fundamental explanation is that transport currently accounts for only 3 % of global carbon dioxide emissions in Paris. Similarly, this figure may seem insignificant, but when compared to other sources of emissions, it is significant: aircraft, a means of transport whose pollution is much more present in society's mind, accounts for 2 % of global CO2 emissions, one point less, while if we put transport on a public scale, it would be the sixth most polluting country on the planet, behind only the United States, China, Russia, India and Japan.[9] The ecological issue came to the fore during the monetary crisis of 1973. The question of ecological and social sustainability became substantial through an extremely articulated expansion of the cost of oil, which is a characteristic asset on which developed nations depend to a large extent.[10]

Due to this lack of oversight, it is estimated that ships could produce up to 17 % of all emissions by 2050, assuming the sector continues to evade regulations. The delay in decarbonisation could lead to a colossal mystery: a significant part of the inventory needed for green progress, from wind turbine blades to electric vehicle batteries, would be transported on board large ships powered by petroleum derivatives and, therefore, exceptionally polluting, to ensure that the green transformation is not entirely flawless.

Seaports are an important part of the beachfront delivery service and are vital in coordinated transport chains and territorial economies. However, ports are also sites of environmental pollution caused by land-based activities, transport tasks, and port operations. It is therefore increasingly recognised that ecological safeguards and social progress must offset monetary development in these areas".[11]

**Navigation risks on Arctic routes**

Due to environmental change, the use of polar routes for transport is increasingly becoming a reality. The liquefaction of ice has opened new doors to the cold, and ships have begun to use these routes as an alternative to the route from the South China Sea through the Suez Canal. Ice melting has opened new doors in the Arctic route, and ships have started using these routes as an option in contrast to the route from the South China Sea through the Suez Canal. The main reasons are the time and fuel reserves saved by the ship".[12]

Activities in polar waters present more difficulties than tasks in other waters due to the particular conditions of these locations and the exceptional circumstances in their locality. The biggest challenge when sailing in these waters is ice. There is ice in these waters. The condition and presence of ice differ significantly depending on the area in which you find yourself. Things change a lot depending on the area you are exploring; sailing in high-reach waters is not the same as sailing in low-reach waters. The reach is higher than the water in the lower reaches. In addition, unexpected conditions should also be considered.

The eccentric conditions of the ice, which change from year to year, must also be considered. In addition to the regular ice conditions, unfavourable weather factors, such as intense storms, heavy rain, and heavy snowfall, must also be considered. Storms, vast oceans, polar fronts, and fog will not cause problems along the way.

*International Proposal Towards Environmental Sustainability*

Towards Ecological Manageability in Ocean Freight Transport. The link between the obligations of the Paris Agreement, the objectives of the 2030 Agenda, and the principles of the World Ocean Organisation, regardless of the difficulties of natural change.[13] The United Nations Framework Convention on Climate Change (UNFCCC), one of the agreements adopted in Rio de Janeiro in 1992, is the primary legitimate global instrument on environmental change, establishing rules, general commitments, and conventions as correlative responsibilities, under the guidance of common but separate responsibilities between meetings. This programme, which has held 197 meetings (expressions that have sanctioned their link), aims to resolve the centralisation of GHGs in the air, particularly carbon dioxide (CO2).

Within the framework of coordinated ocean factors, there are links between supplier and customer organisations. Within this framework, shippers are incorporated as dynamic specialists. It is increasingly common for organisations to integrate manageability into their activities. Social, cutting-edge, and regulatory tensions are increasing the interest and need for organisations to focus more on their production network activities' natural and social effects. Many delivery lines have adopted green shipping practices (GSPs) since the signing of the Paris Agreement (2015) of the United Nations Framework Convention on Climate Change. Regardless of society's importance to this issue, some countries have ports that effectively implement these practices. The Port of San Antonio in Chile is still in the early stages of its efforts. However, it is worth noting that it participates in a public programme called 'Programa

Creación Limpia' (Clean Creation Programme), which seeks to raise awareness of the issue. On the other hand, although this port currently has ISO 14001 certification, international ISPS authorisation, and carbon footprint assessment for 2010, 2011, and 2012, ISO accreditation is not yet available. 50001 which focuses on providing a relationship with the requirements for achieving continuous improvement in energy performance, once leaders have implemented the energy awareness system".[14]

## RESULTS

Greenhouse gas emissions depend on many factors, including the type of ship, activity levels, engine type, and age.

**Table 1.** Greenhouse gas emissions depend on many factors

| ID | Barco | Total emissions | Average emissions | Number of boats (approximate) |
|---|---|---|---|---|
| 1 | Container carrier | $ 212 000 000,00 | 40536 | 5230 |
| 2 | Bulk carriers | $ 175 00 000,00 | 15286 | 11448 |
| 3 | Oil companies | $ 113 000 000,00 | 13623 | 8295 |
| 4 | Vehicle transporters | $ 59 000 000,00 | 15443 | 3821 |
| 5 | methane carriers | $ 43 000 000,00 | 27632 | 1556 |
| 6 | Offshore workboats | $ 50 000 000,00 | 6790 | 7364 |
| 7 | Cargo ships | $ 40 000 000,00 | 3778 | 10588 |
| 8 | Cruises | $ 22 000 000,00 | 50319 | 437 |
| 9 | Fishing boats | $ 12 000 000,00 | 1145 | 10480 |
| 10 | Ferries | $ 1 000 000,00 | 1803 | 555 |

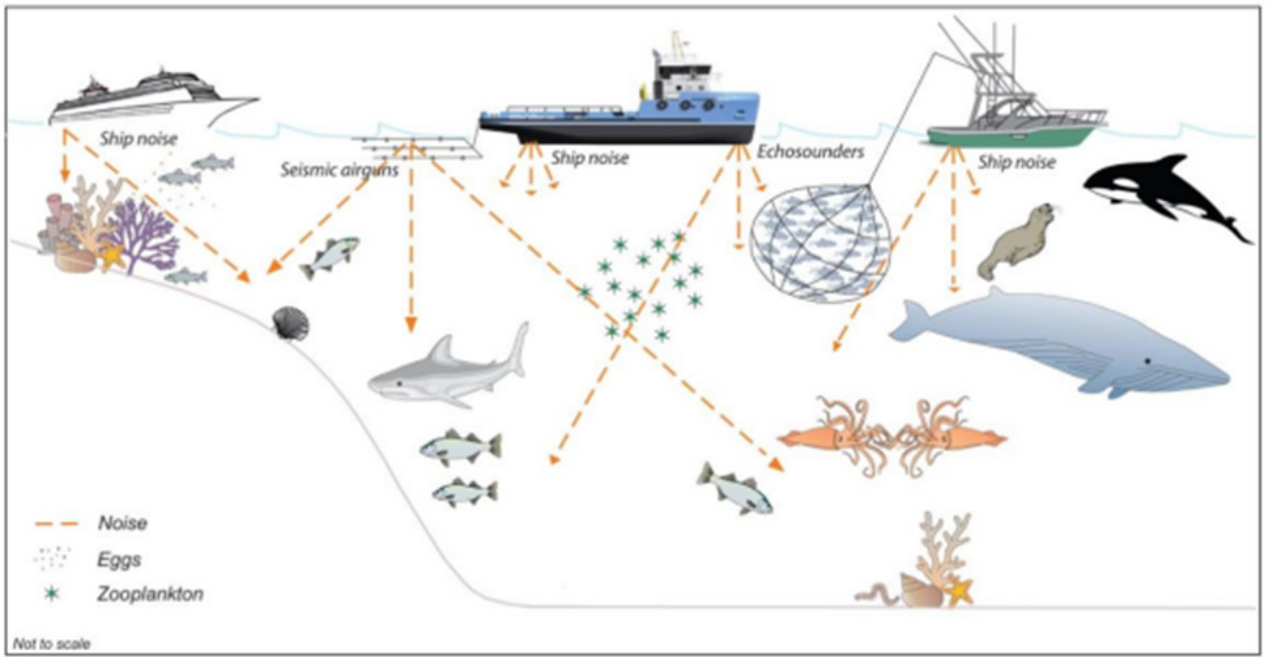
The graph shows that, in terms of average emissions, methane tankers, cruise ships, and container ships are the most polluting. However, in terms of total emissions for that year, container ships, bulk carriers, and oil tankers take the prize, with fishing vessels and ferries being the least polluting, which is related to the number of vessels in these categories.

*Underwater noise*

Underwater noise pollution has gone unnoticed for many years because, unlike airborne noise, the lack of contact with humans meant that the problem remained silent under the sea. However, growing environmental protection awareness in recent decades has drawn attention to underwater noise pollution and its consequences.

Several studies have shown that artificial noise adversely affects marine life and behavior.[15]

This image shows a common source of anthropogenic underwater noise (noise caused by humans) and some of the marine fauna that may be affected by it. The orange arrow represents the wave vector pointing in the direction where the sound can propagate.




**Source:** Costa, D. P.[16]

**Figure 1.** Several studies have shown that artificial noise adversely affects marine life and behaviour

**Table 2.** Some of the observed effects of underwater noise on marine fauna

| Physiological | Behavioural |
|---|---|
| Non-auditory | Perception |
| Damage to body tissues. | Coverage of explicit speech. |
| Possible acceptance of gas embolism | Coverage of other important organic sounds. |
| Possible listing of fat embolism | |
| Possible | |
| Auditory | Behavioural |
| Serious damage to the auditory system | Disorientation and stranding |
| Chronic hearing problem (PTS) | Disruption of normal habits such as feeding, reproduction or nursing |
| Temporary social hearing impairment (TTS) | Adaptive variation in vocalisation, in intensity and/or frequency |
| | Abandonment of the area (short or long term) |

The above impacts are divided into two main categories: physiological impacts, which relate to coordinated consequences for the species' physiological capacity, such as current damage or brief or lasting hearing loss, and general consequences for the species' overall physiological capacity. There are also behavioural impacts related to the way the species behaves in relation to its natural elements, such as diving, swimming patterns, transient movements, etc.

*Causes*

- Mooring of debris (hereinafter debris, as per the English wording). These are essential for developing offshore wind turbines, expansions, and backup for different designs. The effect of the sleds on the seabed produces high-energy eruption sounds (recurrence below 500 Hz).[17]
- Propellers: These are the primary source of underwater noise due to cavitation, or at least the formation of small air pockets at the tips of propellers with sharp edges affected by their rotational speed, where these air pockets burst, causing noise and propeller wear.[18]
- Maritime traffic: ships transmit low-frequency sounds (huge cargo ships) due to internal systems, hydrodynamic currents around the ship's structure, or propeller cavitation.
- Drilling and excavation cause noise levels in small and medium-sized vessels.

*Mitigation*

- Options include spatial and temporal restrictions, limiting activity at or near the source so that eggs can continue their life cycle without adverse consequences.
- Another action is to limit the speed of vessels, thereby reducing noise levels and significantly reducing the impact on marine species. Noise emissions can be reduced by establishing noise limits around the gathering activity, using air, air bubbles, substantial obstructions, or a combination.

*Green alternatives to exhaust emissions*

Demand for cleaner fuels has increased in recent years, as has supply. An increase in the supply of liquefied natural gas to the offshore industry has sparked interest in LNG as a marine fuel.

Gas carriers transporting LNG use LPG cooking gas because liquefied natural gas evaporates due to temperature changes to propel the ship forward.[19]

It has such a significant effect on the development of ozone-depleting substances that there are cut-off points and limitations on fuel use.

HFO and different impurities. The World Maritime Association is responsible for complying with the above limitations to limit the development of substances harmful to the ozone layer. Maritime transport is a more environmentally friendly method of transport. Hence, in 1978, the International Convention for the Prevention of Pollution from Ships (MARPOL) was created.[20]

In this review, the systems were compiled by evaluating the guidelines of the World Maritime Association (IMO), the suggestions of the European Association (EU) and the uses of transport organisations to reduce air pollution from ships, and taking into account the need for these techniques, the impact of procedures in marine regions where ships approach land was analysed using a hybrid method called (AHP-VIKOR).

The procedures created focus on air pollution caused by ships worldwide and gradually portray the degree of impact of these procedures, which is estimated using the Cross Breed Fluffy AHPVIKOR strategy.[21] Consequently, the issue is presented, along with the levels of expertise of the specialists whose opinions were taken into account for the examination and the steps for applying the technique described in the previous section to address this problem.

A study was conducted to analyse practical structural engineering, including diesel generators, solar-based heating systems, and proton exchange membrane fuel cells (PEMFCs). The proposed framework configuration shows an apparent decrease in ozone-depleting substance emissions, approximately 10 %, compared to the baseline. In addition, the reception of energy devices presents the possibility of addressing electrical and nuclear energy, which means savings in the ship's polluting emissions. Another study shows how SOFC-type energy components, integrated into an LNG-powered energy system, are a valid innovation to meet expected heating demands while reducing LNG use by 14 %.[22] The use of nuclear energy storage is another technique for further developing the energy productivity of ships. Implementing these innovations makes it possible to reduce dependence on traditional systems

for generating heat when necessary, such as boilers controlled by petroleum products. Using the intensity of waste produced by the polygeneration system is a fundamental procedure for working on ship productivity and ecological sustainability. Many studies have been conducted on managing the intensity of waste generated by diesel generators and other installed systems.[23,24]

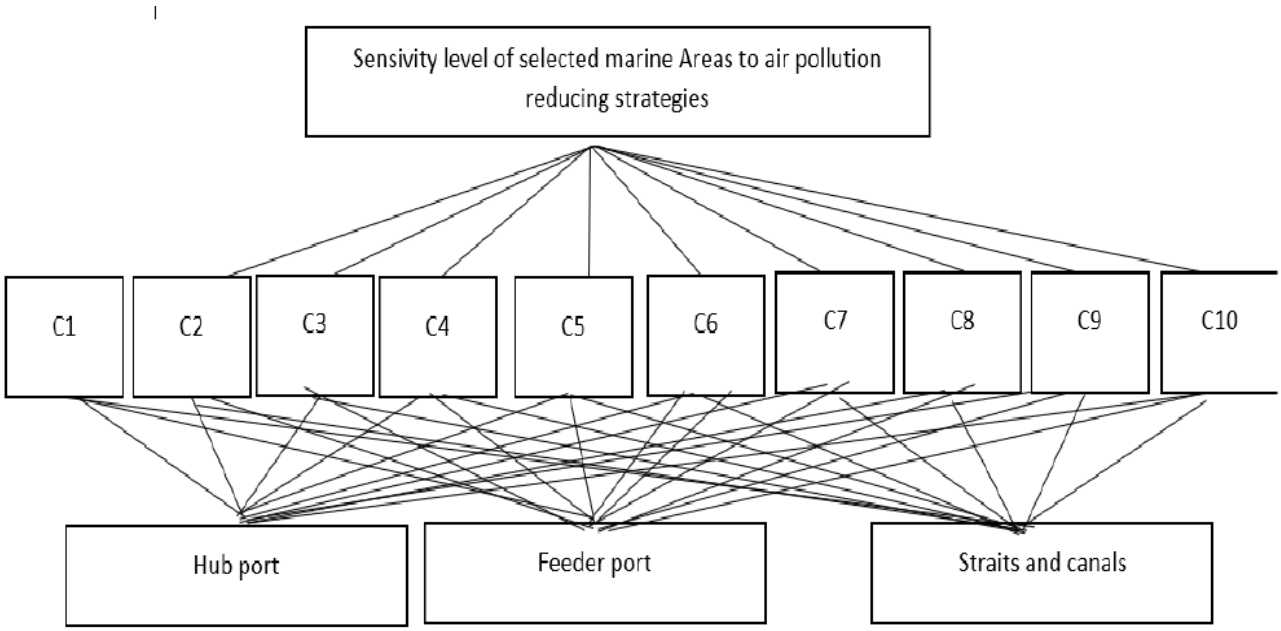



**Figure 2.** Sensivity level of selected marine Areas to air pollution reducing strategies

A simple example of flow output expectations for ships transporting compartments is shown in table 3 for propulsion hardware. In addition, auxiliary engines. The correlation between the output rates evaluated using the two strategies revealed some contrasts between their qualities.[25] The discharge rates evaluated by the EPA for NOX and HC are mostly lower than those obtained using the ENTEC model. Be that as it may, the discharge rate evaluated according to the EPA for CO2 is generally higher than that evaluated using the ENTEC model.[26,27]

**Table 3.** Emission rates using EPA and ENTEC methodologies

| | | | | | Issue rate (kg/h) | |
|---|---|---|---|---|---|---|
| **Engines** | **Fuel type** | **Load factor** | **How it works** | **Air pollutants** | **EPA** | **ENTEC** |
| Main engines | Marine diesel engine | 100 % | Maneuvering mode | NOX, CO2, HC | 87660; 70213 | 108951; 796144 |
| Auxiliary engines | Marine diesel engine | 40 % | Manoeuvring mode | NOX, CO2, HC | 31; 722078; 10; 2 | 32; 720701; 2 |

## DISCUSSION

According to the author Adriana Castro Ruiz in an analysis of the assessment, comparison, and selection of multiple propulsion technologies for maritime transport, she states that NOx, SOx, and CO2 emissions and related regulations are the main reasons for introducing new technologies. Many marine propulsion technologies are currently available or approaching commercial viability shortly. However, many of these technologies, such as nuclear power and wind turbines, are not yet mature or suitable for short and medium distances. Therefore, the most appropriate strategy for reducing emissions and complying with regulations still appears to be focused on internal combustion engines.[28]

In addition, other technological solutions, such as onboard carbon capture, and design solutions, such as more hydrodynamic ships, are being investigated. The possibility of recycling energy from exhaust gases and reusing it on the ship itself is also being considered.

It is important to mention that the transition to these green fuels is challenging due to the specific needs of cargo ships, such as the ability to move large loads over long distances. However, the industry is committed to finding solutions due to the urgency of reducing greenhouse gas emissions.

As evidenced in the article, ships are major polluters of the environment and the ozone layer, harming even marine life. However, due to their large size, ships are the most fundamental means of transport for trade, allowing them to carry large volumes at lower costs. For this reason, sustainable developments have been implemented to reduce the negative impact of ships progressively.[29,30]

## CONCLUSIONS

Over the years, international trade has been fundamental to the global economy, exporting goods and services to different parts of the world through maritime logistics. However, ships significantly negatively impact the environment, and greenhouse gas and

carbon dioxide emissions are also reduced.

To this end, an analysis is carried out of how sustainability (economic, social, and environmental) can be addressed using an approach based on different alternatives affecting service quality, logistical value, and the satisfaction of shipping companies.

This is mainly because ships have a useful life of 25 years, and older ships emit more carbon dioxide and sulphur than modern ships. Another factor is wastewater, which can contain pollutants such as oil, grease, chemicals, and pathogenic microorganisms that affect the climate. After conducting an analysis in which approximately 59 773 ships generate greenhouse gas emissions, with container ships being the most polluting, organisations such as the UNFCCC have established proposals to reduce GHG emissions since the Paris Agreement in 2015 by applying Green Shipping Practices (GSPs).

Currently, ships use an alternative to reduce air pollution and comply with current regulations: the use of purification systems. The aim is to reduce the spread of pollutants and comply with regulations using low-sulphur fuel cleaning systems or low-sulphur fuel. However, with the introduction of new technologies, people are looking for renewable energies and less polluting propulsion methods, so alternatives are gradually being improved so that everyone can be part of and achieve the Sustainable Development Goals.

## FINANCING

None.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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*Writing – review and editing:* Nathalie Raynaud Prado, Marlyn T, Pradilla Vera, German D, Torres Vargas.

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