COMPARATIVE ANALYSIS OF MARITIME AND ROAD TRANSPORTATION IN EMISSIONS PERSPECTIVE

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BY

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I hereby declare that all information in this document has been obtained and presented in accordance with the academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Kevin, NUSA

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DEDICATION

I dedicate this work to Mr. and Mrs. N. Ibrahim my beloved parent, who over the years have shown me unconditional love, as well as undying support in all ramifications of life.

ABSTRACT

The International Maritime Organization (IMO) in its attempt to avert the global environmental crisis continues to provide policies to mitigate anthropogenic emissions from the transport industry. The greenhouse gas emissions from the transport industry are relatively large, alarming, and continue to increase. Therefore, it is the focal point for the fight against global warming. This article reviews transport emissions with a focus limited to maritime and road transport. The purpose of this review article is to compare maritime and road transport from an emission perspective. Thus, it aims to create a source for future studies and to contribute to the existing literature. This study has used the PRISMA method to evaluate and review relevant scientific papers published. For this purpose, sixty-two articles published from 2012-2022 were found through the keywords search. After a screening of the full body text, eight articles were selected for the final review. The data and evidence across the articles reviewed have suggested that maritime transport contributes relatively little to the transport's CO_2 emissions footprint, given the enormous volume of freight transported. This study presents a review that highlights the comparative advantage of maritime and road transport from an emission perspective. It supports the environmental superiority of maritime transport in terms of CO_2 emission and presents an infrastructure for further scientific comparison.

Keywords: Ship emissions; road emissions; GHG emissions; PRISMA; systematic literature review

ÖZET

Günümüzde ulaştırma endüstrisinden kaynaklanan sera gazı emisyonları uluslararası ölçekte endişe haline gelmiştir. Dünya ticaretinin %90'ının denizyolu ile gerçekleştiği göz önüne alındığında gemi kaynaklı hava kirliliği, küresel ısınma ile mücadelenin de temel taşlarından birine dönüşmüştür. Bu noktada Uluslararası Denizcilik Örgütü (IMO), deniz taşımacılığı kaynaklı hava kirliliği ile mücadele için orta ve uzun vadeli hedefler belirlemiş ve bu hedeflere ulaşmak için çeşitli stratejiler geliştirmiştir. Özellikle Deniz Çevresini Koruma Komitesi'nin – Marine Environment Protection Committe (MEPC), gemi kaynaklı hava kirliliğiyle mücadele konusunda son on yıl içerisinde aldığı kararlar dünya ticaret filosunun dinamiklerini değiştirecek niteliktedir.

Deniz aşırı ulaşım gerektirmeyen coğrafyalarda ticaret büyük oranda karayolu taşımacılığı üzerinde işlemektedir. Bunun yanında karayolu taşımacılığı, denizyolu ile entegre olarak uluslararası ticaretin ana arterlerinden birini oluşturmaktadır. Bu tez çalışması, dünya ticaretinin iki majör taşımacılık sistemi olan denizyolu ve karayolunu emisyonlar açısından karşılaştırmaktır. Çalışma kapsamında PRISMA (Preferred Reporting Items for Systematic Reviews and Meta -Analysis) metodu ile sistematik literatür araştırması yapılmış ve bu doğrultuda "gemi emisyonları" ve "karayolu emisyonları" anahtar kelimeleriyle 2012 – 2022 yılları arasında yapılan çalışmalar incelenmiştir. Elde edilen sonuçlar, hem küresel ısınma ve iklim değişikliği temelinde iki ana taşımacılık türünün hava kirliliği ile olan ilişkisine yönelik çalışmaların bilimsel profilini ortaya koymuş hem de gelecek çalışmalar için altyapı oluşturarak literatüre katkı sağlamayı amaçlamıştır.

Anahtar Kelimeler: Gemi emisyonları; karayolu emisyonları; sera gazı emisyonları; PRISMA; sistematik literatür taraması

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1. INTRODUCTION

Living things breathe in oxygen and exhale carbon dioxide. The carbon dioxide exhale is a waste and toxic to the body. In like manner, internal combustion engines used by ships burn a mixture of fuel and air in the combustion chamber. In this process, residual gases are released through the exhaust as waste. Therefore, emissions are substances that are emitted. From the perspective of energy, these are often waste products of a process aimed at obtaining useful work (Energy education, n.d.). Again, from the first law of thermodynamics energy can neither be created nor destroyed, but can only be altered in form. This implies that any process that takes in energy must release energy although in some other forms. The energy released in the form of waste is called emission. Therefore, the carbon dioxide released by living organisms and the residual gas from ship engines all constitutes emission.

Generally, emissions have a number of negative effects on the environment and the quality of life. Numerous sources of emissions contribute several million tons of pollution to the atmosphere on a yearly basis. Climate change is one of the environmental global challenges traceable to global emissions. Greenhouse gases, especially carbon dioxide (CO2) emissions, are viewed as one of the core causes of climate change, and it has become one of the most important environmental problems in the world (Li et al., 2021). The greenhouse gases behalf like a protective cover preventing electromagnetic radiation from leaving the earth's surface. This raises the average temperature on the earth's surface and as a result, snow cover melts into the river. Therefore, the sea level raises overflows causing floods and consequently drought.

Human and environmental health are closely intertwined. Therefore, we must look at emission from a health perspective. A number of life-threatening illnesses and diseases are traceable to pollution resulting from emissions. A review of this evidence indicates that transport-related air pollution affects a number of health outcomes, including mortality, nonallergic respiratory morbidity, allergic illness and symptoms (such as asthma), cardiovascular morbidity, cancer, pregnancy, birth outcomes, and male fertility (Krzyzanowski et al., 2005, p. 125). Emission pollution has noticeable effects on the human respiratory organ. These pollutions are predominant in urban communities with a high level of industrial activities, vehicle traffic, and port operations. When carbon monoxide is inhaled into the respiratory system, it depletes the oxygen content of the bloodstream and causes serious health implications. The respiratory immune system is severely impaired by excess nitrogen oxide in the atmosphere. Particulate Matter (PM) is another pollutant that has devastating effects on human health. About 3.3 million premature deaths per year worldwide are attributable to outdoor air pollution, mostly $PM_{2.5}$, and 54,730 of them in the contiguous United States (Li et al., 2021 as cited in Lelieveld et al., 2015). Particulate emissions in the form of dust emanating from vehicle exhausts as well as from non-exhaust sources such as vehicle and road abrasion, have an impact on air quality (Comtois, et al., 2005). Plants are equally not spared of the damaging effect of emissions. The raise in sea level causes flood and run-off water. This destroys natural vegetation and washes away crops on the farm causing food shortage. Acid rain due to emissions caused impacts crop growth.

Mechanization and industrialization have brought significant changes to our society. Mechanization allows farmers to use machines to improve their productivity. Access to electricity makes life easier and more convenient. Raw materials, crudes, and spares are now able to reach previously inaccessible destinations even in sufficiently large quantities. This has improved manufacturing and productivity. Nevertheless, a number of challenges characterize these developments. Infrastructural expansion and urban expansion are taking up natural vegetation and depleting the global supply of oxygen. The global use of fossil fuel, charcoal, and firewood for energy to drive fabricated machines continues to contribute to anthropogenic emissions, which is a catalyst to global climate change. Ships are powered by energy derived from these sources and they are responsible for the movement of three-quarters of the world’s freight (ITF 2019 as cited in Gössling et al., 2021). Therefore, due to the volume of ocean-going vessels, the pollution emitted by ships is enormous. Air quality issues are extremely important for both occupational and environmental health (Mueller et al., 2011, p. 1). The pollution from ships is prevailing in the coastal areas but a quickly propagated by onshore winds into urban settlements where they mix with other pollutants.
International world trade will immediately collapse without shipping. Shipping is regarded as the back born of international trade. However, the industry is associated with air pollution and contributes significantly to anthropologic emissions. In the process of consuming fuel oil, the main engine, auxiliary engine, and boiler of a ship will produce carbon dioxide (CO2), nitrogen oxides (NOx), sulphur oxides (SOx), carbon monoxide (CO), Unburned

coals (HC), and particulate matter (PM2.5, PM10) (Dong et al., 2022). These substances emitted through the exhaust constitute great harm to the environment. Ship-source pollutants most closely linked to climate change and public health impacts include carbon dioxide (CO_2), nitrogen oxides (NO_x), sulphur oxides (SO_x), and particulate matter (PM). (Clear Seas, n.d). On a global scale, the marine shipping industry's share of total emissions from human sources is CO_2 2.2%, NO_x 15%, and SO_x 13%, per year (Clear Seas, n.d). This makeup the greenhouse gas responsible for global temperature raise and other respiratory diseases.

The International Maritime Organization (IMO) in 1973 adopted the convention for the prevention of pollution by ships (MARPOL) which is the international convention responsible for the prevention of pollution in the marine environment. The convention is empowered with the responsibility of giving standards for stowing, handling, shipping, and transfer of toxic waste as well as proposing rules regarding the disposal of ship-generated hazardous waste like cleaning agents and cargo hold washing water. It has since proposed six annexes with the latest being annex VI for the Prevention of Air Pollution from Ships. Others include annex I Regulation for the Prevention of Pollution by Oil; annex II Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk; annex III Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form; annex IV Prevention of Pollution by Sewage from Ships; and annex V Prevention of Pollution by Garbage from Ships. On 10 October 2008, the IMO adopted the revised Annex VI, which sets out the framework for limiting emissions of nitrogen oxide (NO_x), Sulphur oxide (SO_x), and particulate matter from ship exhausts (Dickson et al., 2022). Therefore, this article is limited to the scope of annex VI. Table 1.1 includes the regulations of IMO to combat ship-borne air pollution and shows the future targets.

Table 1.1: IMO regulations/targets made in the last decade within the scope of reducing greenhouse gas emissions from transportation (IMO, n.d.).

Regulations	Projects/Implementation support	Year
Adoption of energy efficiency design index (EEDI) and Ship energy efficiency management plan (SEEMP). It is the first legally binding treaty regarding climate change since Kyoto Protocol.	KOICA (Korea International Co-operation Agency) and the IMO GHG entered into an agreement to implement a technical cooperation project on building capacities in East Asian countries to address GHG emissions from ships	2011
-	"Mitigation of climate change" Global Programme included in IMO's Integrated Technical Cooperation Programme (ITCP), later renamed as "Energy Efficiency" Global Programme	2012
The provisions of EEDI and SEEMP were enforced	Promotion of technical cooperation and transfer of tech-oriented improvements tailored towards ships' energy efficiency	2013
Approval of the Third IMO GHG Study 2014 (October 2014)	-	2014

Table 1.1: IMO regulations/targets made in the last decade within the scope of reducing greenhouse gas emissions from transportation (Continue) (IMO, n.d.).

Regulations	Projects/Implementation support	Year
Energy Efficiency Design Index (EEDI) enforced a 10 percent reduction in carbon emission intensity as a phase 1 requirement	Pilots from Argentina, China, Georgia, India, Jamaica, Malaysia, Morocco, Panama, Philippines, and South Africa make up the lead Pilot country that launched the Global Maritime Energy Efficiency Partnerships Project (GloMEEP)-a Global Environment Facility (GEF)-United Nations Development Programme (UNDP)-IMO project	2015
The Data collection system which requires ships of 5,000GT and above to report their fuel oil consumption of ships was enforced	-	2016
-	Global network of five regional Maritime Technology Cooperation Centres (MTCCs) launched under IMO-executed Launched The Global Industry Alliance (GIA) as a public-private partnership towards achieving low energy efficiency and low carbon emission, it’s an initiative of the IMO through the GloMEEP program The European Union founded the GMN project as a means to promoting technology and operation to improve energy efficiency.	2017

Table 1.1: IMO regulations/targets made in the last decade within the scope of reducing greenhouse gas emissions from transportation (Continue) (IMO, n.d.).

Regulations	Projects/Implementation support	Year
IMO Maritime Environment Protection Committee (MEPC) as their first attempt to address GHG from ships met in April of 2018. It initiated and adopted the IMO strategy envisioned to reduce GHG emissions from international shipping and, as a matter of urgency, to phase them out as soon as possible within the century	The Global Environment Facility (GEF), the United Nations Development Programme (UNDP), and the International Maritime Organization (IMO) in collaboration launched The GloFouling Partnerships project. The project was spearheaded by a mix of twelve developing nations and small developing island states with the aim to address the build-up of aquatic organisms on a ship's underwater hull and on other marine mobile infrastructure	2018
In the seventy-forth session, MEPC adopt a Procedure for assessing the impacts on States of candidate measures Enforcement of the previously adopted resolution on Data collection system for fuel oil consumption of ships,	Establish a trust fund for IMO GHG Technical Cooperation IMO Symposium on IMO 2020 sulphur limit and Alternative Fuels Resolution to involve the member states to encourage voluntary cooperation between the port and shipping sectors to contribute towards the reduction of ships' GHG emissions The IMO in cooperation with the Norwegian government enter into a partnership aimed to transform the shipping industry along a low-carbon future	2019

Table 1.1: IMO regulations/targets made in the last decade within the scope of reducing greenhouse gas emissions from transportation (Continue) (IMO, n.d.).

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Approval of the Fourth IMO GHG Study 2020 (November 2020) As a phase 2 requirement, Energy Efficiency Design Index (EEDI) effect a 20 percent reduction in carbon emission intensity for all new ships.	GloFouling Partnerships Project IMO and the Republic of Korea enter into a partnership to establish a training program to support developing countries address ships' GHG emissions IMO -EBRDWorld Bank FIN-SMART Roundtable was launched to fund sustainable Maritime Transport Marine Environment Protection Committee adopted Resolution MEPC.327(75) to encourage Member States to develop and submit voluntary National Action Plans to address ship's GHG emissions	2020

Table 1.1: IMO regulations/targets made in the last decade within the scope of reducing greenhouse gas emissions from transportation (Continue) (IMO, n.d.).

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Table 1.1: IMO regulations/targets made in the last decade within the scope of reducing greenhouse gas emissions from transportation (Continue) (IMO, n.d.).

Regulations	Projects/Implementation support	Year
-	In 2021 The IMO held a Symposium on alternative low-carbon and zero-carbon fuels for shipping was held IMO and Germany entered into an ambitious project (Blue Solutions Project) with the aim of finding opportunities to prevent GHG in East and Southeast Asia countries. The IMO in cooperation with Singapore launches NEXTGEN connect centered towards maritime decarburization The IMO and the United Nations Environmental Programme (UNEP) launched a zero and low-emission forum aimed at promoting innovation by providing a global platform for the exchange of knowledge. Initiate consideration of mid-term measures under Phase I of the Workplan Recognize the need for assessment of impact states, especially developing states and small developing island states.	2021

Table 1.1: IMO regulations/targets made in the last decade within the scope of reducing greenhouse gas emissions from transportation (Continue) (IMO, n.d.).

Regulations	Projects/Implementation support	Year
EEDI phase 3 in effect for certain ship types with up to 50% carbon intensity reduction for new build large containerships The Energy Efficiency Existing Ship Index (EEXI) survey requirements took effect	-	2022
Effect Carbon intensity measurement Adopt the revised IMO Strategy toward Ship's GHG emission Reduction Rules on reporting of ship's annual operational carbon intensity indicator (CII) rating enter into force	-	2023
Phase 3 calls for all new build vessels to achieve at least a 30% reduction in carbon intensity	-	2025
The IMO Initial GHG Strategy envisages an average of 40% reduction in CO2 emission per transport work for international shipping in respect to 2008	-	2030

Table 1.1: IMO regulations/targets made in the last decade within the scope of reducing greenhouse gas emissions from transportation (Continue) (IMO, n.d.).

Regulations	Projects/Implementation support	Year
IMO Initial GHG Strategy objectives of a 50% reduction of the total annual GHG emissions and 70% reduction of CO2 emissions per transport work with respect to 2008 while intensifying efforts towards zero ship-related emission – as a point on a pathway of CO2 emissions reduction resonance with the Paris Agreement temperature goals	-	2050

1.1. Purpose and Importance of Thesis

Transportation modes are easily classified base on the medium they engage. Given this, land transportation, maritime transportation, and air transportation are easily identified from their engagement with the land, bodies of water, and air space respectively for the movement of freight and passengers both locally and across the globe. Land transportation is an umbrella name that encapsulates road, railway, and pipeline transportation. This article aims at comparing road emissions and maritime emissions; the motivation of this study is to draw attention to their environmental effects by compiling studies comparing the two transportation systems in terms of emissions.

1.2. Literature Review

Road transport, therefore, is that form of land transportation that engages the road network, facilitated by trucks, public buses, and private cars among others; it is regarded as the most dominant mode of transportation available to man today. This is due to its easy accessibility, reliability, flexibility, low capital cost, and low infrastructure cost. On the other hand, maritime transportation is the movement of freight or passengers, particularly in huge amounts via ships over a body of water. It could be on oceans, coasts, seas, lakes, rivers, or channels. It engages physical properties like buoyance and fluid friction to transport immensely large volume of freight economically and efficiently over significantly long distances on water. For this reason, it is regarded as the facilitator of international trade. Maritime infrastructures such as ports, ships, channels, waterways, and navigational locks are capital intensive, thereby creating a barrel for new investors due to the immense initial capital cost.

There is a continuous growing concern for the environment by world leaders and environmental experts due to the accelerating environmental deterioration. This is largely due to anthropogenic greenhouse gas emissions (GHG). Greenhouse gases are the gases in the earth's atmosphere that behave like a "blanket" covering the earth's surface, though they allow sunlight to pass through them, they prevent the heat radiated from the sun from leaving the earth's surface. Therefore, GHG is like a heat trap causing global temperature to rise (Fecht, 2021). Carbon dioxide (CO2), water vapor (H2O), methane (CH4), nitrous oxide (N2O), and ozone (O3) are the most important greenhouse gases in Earth's atmosphere. Globally, the transport sectors contribute about 30% to 40% of anthropogenic carbon monoxide and nitrogen oxides emissions, respectively, and about 25% of anthropogenic Non-Methane Hydrocarbon Compounds, NMHCs (Cozic et al., 2010). Exhaust carbon dioxide (CO2) from transportation and power generation could be regarded as a serious pollutant in terms of its global-warming potential (Votsmeier et al., 2019). Therefore, this will be the center point of our comparison.

Since the beginning of the industrial era, man has relied on the burning of fossil fuels for energy. Energy derived from fossil fuels is essentially used for power generation, transportation, agriculture, industry, and heating among which transportation accounts for the highest percentage. In the United States, transportation activities account for 27% of greenhouse gas (The United States Environmental Protection Agency, n.d.). While, in the European Union (EU) context, the transport sector accounts for almost one-third of total EU energy consumption, which generates high environmental costs (Vallejo-Pinto et al., 2019). This is not surprising, as a good percentage of the fuel used for transportation and transport-related activities is derive from fossil fuels. Therefore, with globalization, and increased freight demand, transportation accounts for a growing share of the total amount of energy spent for implementing, operating, and maintaining the international range and scope of human activities, which is today the consequence of the high percentage of greenhouse gas from the industry. This in its sense negates The United Nations (UN) definition and principle of sustainability, which is “meeting the needs of the present without compromising the ability of future generations to meet their own needs.” (Patterson, 2022). In light of this definition, environmental sustainability is utilizing environmental resources in a way and manner that do not compromise the needs of the future generation. However, efforts are already in place to combat the effect of greenhouse emissions, two of which are the Kyoto Protocol and the Paris international agreement of 1997 and 2015 respectively. While these agreements are critical steps toward achieving a safer environment, state enforcement remains a challenge.

In order to reduce total emissions and achieve the Kyoto Protocol or the Paris Agreement, policy maker must look at the sector with the highest percentage of emission contribution. Already, amidst power generation, transportation, agriculture, industry, and heating, research has shown that power generation and transportation are the highest contributors to anthropogenic greenhouse gas emissions (Ritchie et al., 2020). The focus of the article will be on transportation emissions (comparison between ship and road) since the energy intensity and GHG emissions in transport depend on the available transport infrastructure, choice of suitable vehicles, quantity and nature of the transported goods and the traction or fuel used (Skrúcaný, 2018). Transportation as earlier stated is a compound name that comprises land, maritime, and air transport. Road transportation and shipping are the largest global source of GHGs and related pollutants. There has been great improvement in IC engines and exhaust control technology consequent to the continuous strict emission regulations. However, in land transport, the road is the mode mainly responsible for additional energy demands over the last 25 years accounting for an average of 85 percent of the total energy used by the transport sector in developed countries (Comtois et al., 2006).

On the other hand, maritime transportation is one of the environmentally friendly modes of transport (European Environment Agency, 2023). However, with over 90 percent of world trade carried out via seas by 90,000 vessels (Kodak, 2022), it is an established source of GHG and air pollution. According to data from the International Maritime Organization (IMO), more than 3% of global carbon dioxide emissions could be attributed to ocean-going ships (Kodak, 2022). Although international organizations have formulated relevant environmental regulation programs and emission reduction measures, different ports have different resource endowments and are in development stages, and they lack clear technical standards and systematic green technology guidelines (Lin et al., 2022). In comparison to on-road vehicles, regulations for controlling ship emissions are new (IMO, 2005; Khan et al., 2013). Therefore, Seaborne shipping demand continues to grow because of its competitive freight and its capacity to move an enormous cargo volume in an eco-friendly and safe manner compared to other transport modes (Md Moshiul et al., 2021), ship emissions are still very much under-regulated.

From a holistic point of view, all transport mode offers some form of merits and demerits. Comparison only helps us to understand which is best for each circumstance. The fist aim in today's fight against transport GHG emissions is not a total elimination of anthropogenic transport emissions sources but a reduction of these sources such that environmental sustainability is assured initially. Today, Maritime transportation remains relatively the least contributor to atmospheric emissions. There has been a substantial reduction in marine pollution over the last 15 years, especially with regard to the amount of oil spilled into the sea, despite a massive increase in world seaborne trade (ICS, n.d.). In addition, due to improvements in engine design, hull design, shape, and overall size of marine vessels, there has been an appreciable increment in ship cargo carrying capacities. This has also improved significantly the CO_2 emission per tonne per Kilometer travel. However, according to the IMO Conventions, ships are to be constructed with an immediate reduction in greenhouse gas (GHG) emissions of 15%, then 20% by 2020, and 30% by 2025 (Lee & Nam, 2017). The reason is that the enormous scale of the industry means that it is nevertheless a significant contributor to the world's total greenhouse gas emissions, which is around 3% of total global CO_2 emissions (ICS, n.d.). Therefore, International organizations continue to tighten regulations on ship emissions toward the realization of their ambitions, which will further strengthen the maritime sector as the friendliest mode of transportation.

Today, studies based on the instantaneous monitoring of ships have gained importance for the calculation of ship traffic emissions. At this point, one of the most important and current studies carried out is the instant measurement of harmful emissions of ships passing through the Strait of Istanbul. The Istanbul University and the South Korean National Research Foundation (NRF) are working in collaboration to carry out the project. The project is called Air Emission Inventory Analysis from Ships Passing the strait and it aims to measure the emission of ships passing through the strait with the aid of sensors installed at three locations (Daily Sabah, 2022).

In a study by Ülker et al. (2021), the highway emissions of a particular route in the Marmara Region of Turkey were compared with the corresponding seaway distance. The study measured and compared the ship-generated CO2 emission of 13 ro-ro and ferry lines (RFLs) in the Sea of Marmara when it been used to transport vehicles to the CO2 emission generated if the vehicles were to move by road themselves. From the article, the CO2 emission generated by the RFLs in moving the vehicles is 204,470.99 and 170,459.85 t/year, using the Entec UK Ltd, Trozzi, and Vaccaro methods respectively. While on the other hand, the potential CO2 emission generated by road vehicles in 2017, 2018, and 2019 are 121,690.54, 106,844.89, and 100,921.95 t/year respectively. The CO2 emission of RFLs varies according to the traveling distance, speed, number of voyages, available engine power, as well as the method of emission calculation. To this end, the CO2 emission varies across the 13 RFLs. From the available data, it is a matter of little consideration that the number favours road vehicle over RFLs. It is also evidence from the result, that the RFLs do not portray the environmental superiority of ship transport. The superiority of ship transport could have been appreciated if the comparison were made with the bulk carriers as against RFLs. They have more cargo carrying capacity and move at low speed. The study therefore recommends proper evaluation of load carried, the sea advantage factor, and the engine power so as to obtain environmental and economic sustainability.

Emissions were calculated using the Tier 1 method. The research has that the road emission budget surpassed that of the shipping budget. In emission comparison, it is concluded from the article that the annual CO2 emission budget can be reduced if the road truck is shifted to the sea route.

In a study by Dujmovic et al. (2022), carbon emissions comparisons were made between maritime and road transport on selected routes between Italy and Croatia in the Adriatic regions. The selected routes were Venice–Pula–Poreč (R1), Ancona–Zadar (R2), and Bari–Dubrovnik (R3). The article utilized the engine fuel consumption of the reference vessel for the corresponding engine power on the particular route and timetable to calculate the ship emission. The route timetables were based on 2019 data. On the other hand, publicly available emission factors for average personal cars and public buses were used as the standpoint to calculate road CO2 emissions. Therefore, 135.7 gCO2/vehicle-km, which is the average emission for newly registered cars in 2011, was used to compute the average road CO2 emission. Thus, the article made a detailed comparison between the occupancy rate and the selected mode in relation to carbon emission efficiency. The occupancy rate in this context is a relationship between the number of passengers in a given transport system to the maximum number of passengers the transport system can support or move on a given trip through a given route. Table 1.2 shows the CO2 emission of the different modes of transportation through the different routes.

Table 1.2: CO2 emission of the modes at 100% occupancy rate. (Dujmovic et al. 2022)

Route	**Public bus (kgCO2/trip)**	**Personal car (kgCO2/trip)**	**Vessel (wCI) (kgCO2/trip)**	**Vessel (woCI) (kgCO2/trip)**
R1S1	1,191	2,534	2,098	2,934
R1S2	236	502	863	924
R1S3	1,052	2,239	1,281	2,347
R2	14020	30482	12550	32,680
R3	26,499	57,616	28,753	43,753

Note: Adapted from “Emphasis on Occupancy Rates in Carbon Emission Comparison for Maritime and Road Passenger Transportation Modes” by Dujmovic et al. 2022, Carbon Management. Copyright 2017 by Taylor and Francis Group.

R1 contains three segments (see Table 1.2). Venice–Pula (*R*1*S*1), Pula–Poreˇc (*R*1*S*2), and Poreˇc–Venice (*R*1*S*3).

In reality, occupancy rates are mostly below 100 percent. From the above table, it is clear that the public bus produces the least CO2 emission with the marine vessel only having a slightly better CO2 emission at R2 (Zadar–Ancona) and this is largely due to the considerable long distance. Again, the article shows that as the occupancy rate reduces the CO2 emission produced increases. Table 1.3 below shows the on-read and on-sea distance of each route.

Table 1.3: Distance on each route (Dujmovic et al. 2022)

Route	Sea distance (Nm)	Highway distance (km)
R1S1	76.2	283
R1S2	30.4	56
R1S3	60.7	250
R2	864	91.4
R3	108.9	1633

Note: Adapted from “Emphasis on Occupancy Rates in Carbon Emission Comparison for Maritime and Road Passenger Transportation Modes” by Dujmovic et al. 2022, Carbon Management. Copyright 2017 by Taylor and Francis Group.

The occupancy rate and passenger demand are recipes for an optimal transportation mode choice in terms of carbon emission efficiency (Dujmovic et al., 2022).

In another study by (Vallejo-Pinto et al., 2019) the need to focus on the main objective of a possible reduction in global greenhouse gas emissions as against a mere mode shift was emphasized. To that effect, the article proposed the Iso-emission map, which is a systematic tool that compares road transport (only road) and maritime transport alternatives. It emphasizes that the comparison should not be geared solely towards financial and time efficiency but also within the geographical scope of identifying the best alternative in terms of air emissions. He, therefore, concluded that a reduction in air emission could be achieved for many origin-destination pairs by simply continuously shifting traffic from road to Motorway of the sea (MoS), and vice versa.

A comparison between maritime and road transport as it relates to the total cost of environmental externalities was reported by (Castells et al., 2012). The Container ship, RoRo, ConRo, and RoPax were the four ships type considered under three baseline scenarios. These four ships were placed in a side-by-side comparison and their environmental ranking was tabulated as shown in Table 1.4 below.

Table 1.4: Environmental performance summary (Castells et al., 2012).

	Road transport (€/tm.km)	Maritime transport			
		Container Ship (€/tm.km)	ConRO (€/tm.km)	RoRo (€/tm.km)	Ropax (€/tm.km)
Baseline 2012	0.0029	0.0008	0.0015	0.0016	-
RoPax 2012	0.0029	-	-	-	0.0073
Baseline 2020	0.0015	0.00052	0.0009	0.0027	0.0058

According to mentioned study results, maritime transport was considered one of the most environmentally friendly modes of transport. However, results from this model show that it is still a significant source of air pollution with RoRo and RoPax as major contributors to ship emissions. In this context, the study points out that it is already difficult for ships to comply with the already approve strict emission regulations. Therefore, it is recommended to use newly developed greening technology to reduce emissions and ensure sustainability in the system.

Svindland, M., & Hjelle, H.M. (2019) made an attempt to challenge the environmental superiority of maritime transport over road haulage. Their report aims at reviewing the emission level of ocean-going vessels by collecting empirical data on current real-life ship emissions and comparing them with previously reported data. Therefore, it is safe to say that the report focused on comparing ship emissions to road emissions with an intention to challenge and investigate the environmental supremacy of maritime transport. The report categorized shipping freight into smaller feeder vessel SFV (323 TEU, 4544 dwt), Medium feeder vessel MFV (458 TEU, 7750 dwt), and largest feeder vessel LFV (679 TEU, 8199 dwt), with average CO2 efficiency of 718 g/TEU-km, 582 g per TEU-km and 654 g CO2 per TEU-km respectively. The CO2 efficiency of road transport at 0%, 50%, and 100% backhaul load factors was compared across the three categories of shipping freight. Obtained results show that even the worst CO2 efficiency of ship freight surpasses the best road haulage thought by only a margin. Therefore, the report confirms and further strengthens the environmental superiority of maritime transport.

Freight Routing and Emissions Analysis Tool (FREAT) is a spreadsheet tool developed by James J. Corbett, Ph.D., P.E. His tool focus on the tradeoff between land base transportation (trucking routes) and maritime transportation (short sea routes). The FREAT is a multimodal transportation system developed to achieve three objectives, one of which is to select a chain of routes suitable with the desired modal combination with a view of an overall reduction in travel emissions alongside an increase in financial and time efficiency. He reported that shipping and trucking could be compared based on several perimeters or constraints. If time is the constraint at an instance, then trucking is considered. On the other hand, if emission and cost are to be considered where time is not a constraint, shipping takes the lead. Results from the report further showed that for the same traveling route, shipping requires a third of the energy required by trucks.

In another study by Skrúcaný et al (2018), road, rail, and sea transport were compared in terms of transportation, energy requirements, energy consumption, and greenhouse gas emissions. The report was able to group the energy consumption and the GHG emission of transportation into two sections namely, well-to-tank-(WtT), which is the energy required to produce and distribute the needed energy in the first place. These are referred to as secondary energy consumption sources. The other is the Tank-to-wheel (TtW) – this represents the energy directly connected to the transportation of freight and passengers, otherwise referred to as the primary energy consumption sources. Both sources could be fossil fuel or electricity sources. Electric-powered vehicles are considered zero-emission during TtW, in this stage; the vehicle literally produces no emission. However, secondary energy consumption requires electric energy whose production could most likely not be zero-emission, especially if the primary energy source of electricity is the coal power plant. Emissions are therefore intensive contributing immensely to greenhouse emissions and by extension global warming even though the final products are zero emission. This is just the case with electric vehicles. Other fossil fuel-powered engine used across the road and maritime transport consumes energy and produce GHG emission. The conclusion, therefore, can be summarized in Figures 1.1 and 1.2 below.

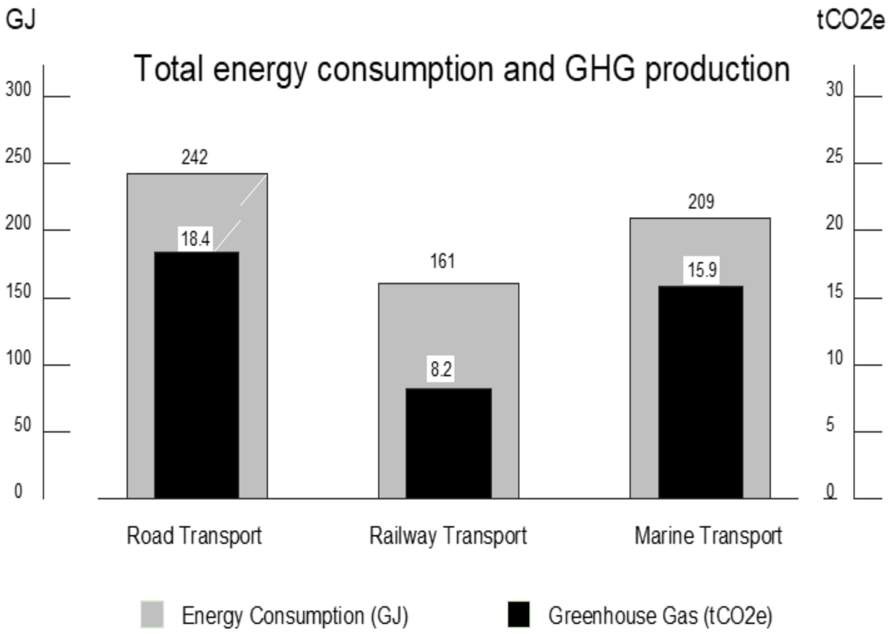

Figure 1.1: Total energy consumption and GHG production (Skrúcaný, 2018)

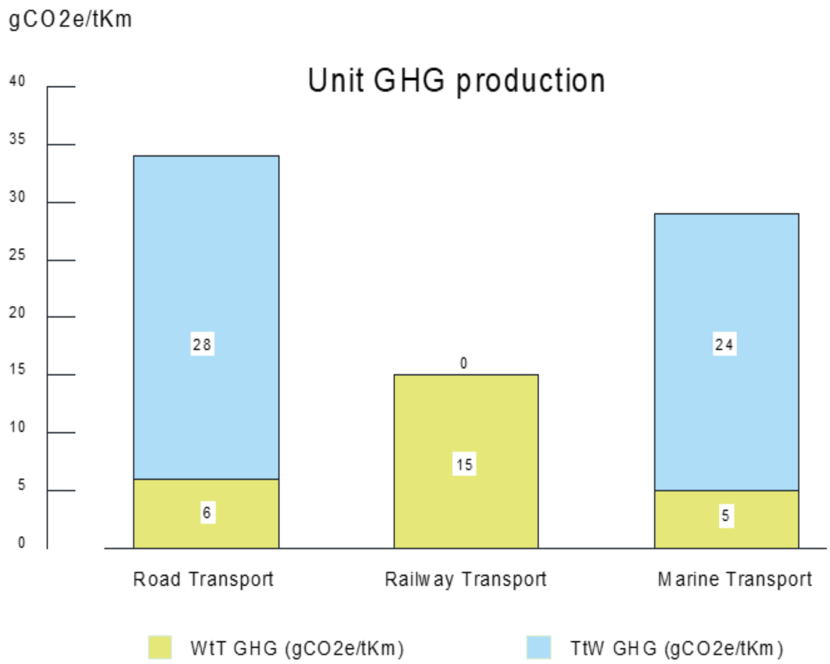

Figure 1.2: Unit of GHG production (Skrúcaný, 2018)

The findings of the study showed that although environmental sustainability is taken into account, rail transport takes the lead. Another result that the study draws attention to is that considering the amount of cargo carried, maritime transportation has the least energy requirement and minimum greenhouse gas emissions to the environment.

Finally, Srinivasan & Poongavanam (2017) made a mathematical analysis, comparing emissions between road and maritime transportation. The study focused on the comparative COx analysis of road and maritime transport between Hyundai (Chennai OEM) and Gandhidham (Gujarat) as a way to understudy the eco-friendliness of each mode. The study results have shown that the COx emission of road transport surpasses ship transport. Furthermore, it affirms that ship transports are much more eco-friendly in terms of their Cox footprint, although it is still a significant source of Sulphur oxide and Nitrous oxide pollution. Therefore study, recommends an expansion of ship transport infrastructure and an increase in government incentives toward the support of coastal shipping.

2. MATERIAL AND METHOD

Literature reviews provide a comprehensive consolidation and evaluation of literature in a specific field of knowledge, as well as identify gaps in the field's body of knowledge that should be filled to further develop the field (Tranfield et al., 2003, as cited in Raza et al., 2020). In this review article, the research tries to align itself with the method of systematic literature review and reporting. More specifically, it uses the Preferred Reporting Items for Systematic Reviews and Meta-Analyses, otherwise known as PRISMA for reporting and evaluation of the literature review.

The process to identify the relevant keywords for the literature review is fundamental to the success of the study since the study is geared towards an emission comparison alone roads and maritime transport. The keywords were chosen within the scope of the topic and intended findings. The keywords are as follows: maritime emissions, road emissions, and GHG emissions. This study used a dataset generated by keyword filtering on the google scholar and semantic scholar portals to evaluate emissions comparison of maritime and road transport. PRISMA, the review method for this study, avoids the complexity that may occur during research. With this method, the boundaries of which are drawn with keywords, a systematic review is provided. Accordingly, the study only took into account the articles that examine or compare maritime and road transport in terms of emissions. In addition, articles examining greenhouse gas emissions and environmental/transport sustainability related to ships and road vehicles were also evaluated within the research. The study is limited to emission from maritime and road transportation, therefore emissions from aircraft were not considered. The literature review was carried out as of December 2022. Only studies in English between 2012 – 2022 were included in the study. The review also considered synonyms of the keywords such as road emissions could be reported as vehicle emissions, GHG emissions could be reported as CO2 emissions or air pollution, and environmental sustainability could be reported as climate change or emission performance. The use of Boolean operators (AND & OR) was particularly useful to include or exclude search keywords. The snowball method was also used twice to avoid the risk of excluding important articles. The literature review was carried out Google Scholar and Sematic Scholar databases, due to their robustness in scientific research papers and their user-friendliness. In addition, the reports prepared by National Geography, Our World in Data and the European Environment Agency (EEA) were included in the research as it is directly related to the subject.

Articles that over-emphasized modal shifts due to monetary and social considerations at the expanse of the environment or without adequate consideration for environmental sustainability were excluded. It this context, it is possible to say that the comparison aims to identify the most environmentally sustainable transport mode.

Studies that narrowed down its review to emissions from public buses, trucks, and passenger vehicles only were excluded. Similarly, studies examining only maritime emissions were excluded. Lastly, studies that review transportation emissions and GHG gasses without specific reference to transportation mode or emissions generated from transportation mode were equally excluded. As a result of the research, 8 articles that met the eligibility criteria were obtained.

Thus, the profile of the studies obtained after the filtering process can be explained as follows.

i. Articles that analyzed maritime and road emissions.
ii. Articles that draw technical comparisons between maritime and road emissions with a view to highlighting possible mode shifts.
iii. Those articles that made their analysis within the context of social, economic, and environmental considerations.
iv. In addition, the articles that analyze transport sustainability especially as it relates to the environment.

Keywords are decisive in this study and Table 2.1 shows the number of articles carrying each keyword.

Table 2.1: Number of articles showing the keywords (Nusa and Kodak, 2023).

Keywords	Number of articles
GHG/CO2 emissions	44
Road emission/transport	14
Ship transport/short-sea shipping	18
Environmental Performance/sustainability	29
Transport Mode	14
Mode shift	7
Freight Transport	7

The studies obtained as a result of the literature review are given in Table 3.1 with the title, author, and keyword information. The research method is given in Figure 2.1 below.

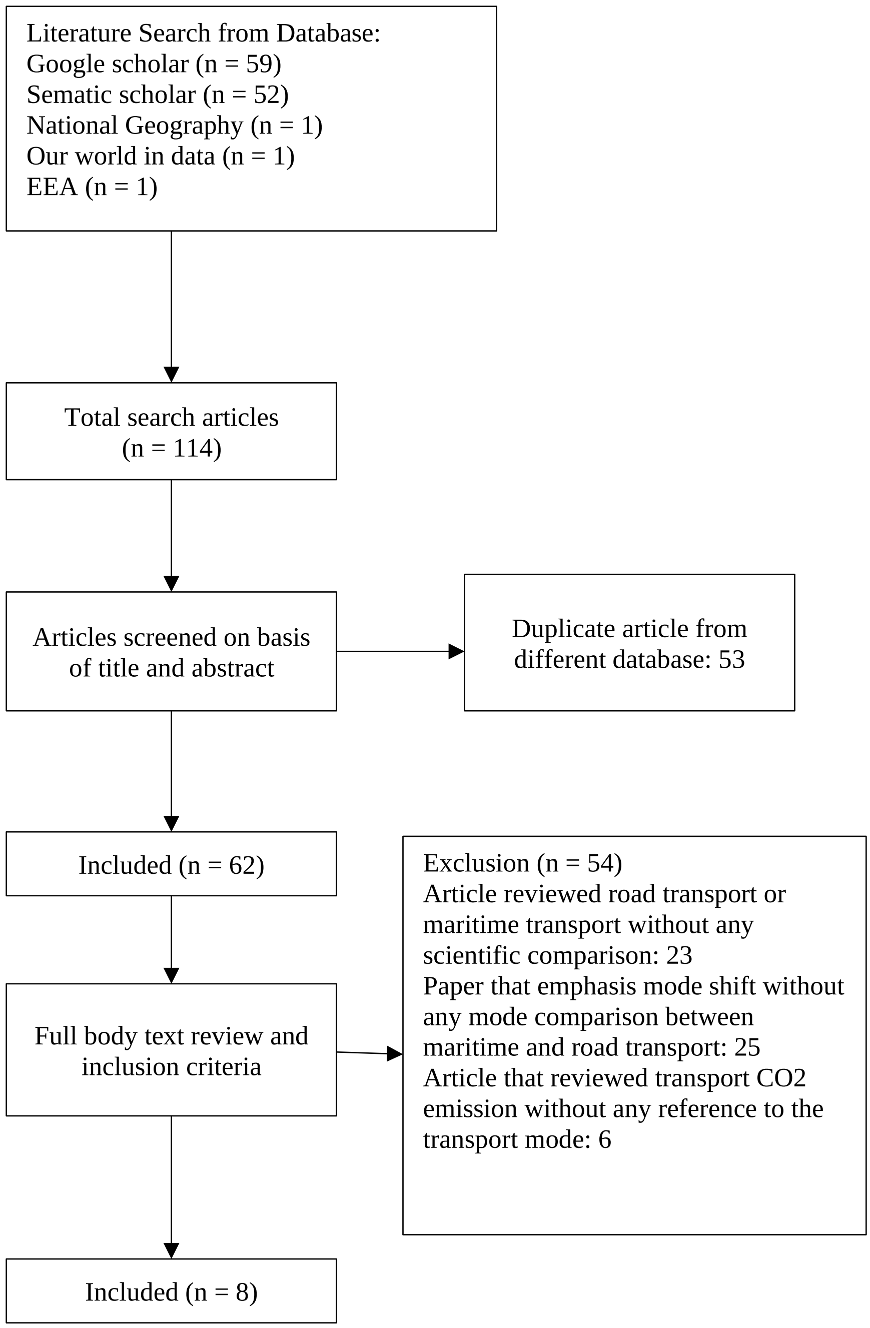

Figure 2.1: Application of the PRISMA method to the study

3. RESULT AND DISCUSSIONS

From a holistic point of view, all transport mode offers some form of merits and demerits. Comparison only helps us to understand which is best for each circumstance. The first aim in today's fight against transport GHG emissions is not a total elimination of anthropogenic transport emissions sources but a reduction of these sources such that environmental sustainability is assured initially. Today, maritime transport is on its way to being the transport system that contributes the least to atmospheric emissions, especially in terms of unit cargo volume transported, in line with IMO's targets and regulations. Thanks to the improvements made within the scope of energy efficiency, CO2 emissions per ton have been significantly improved. However, according to the IMO Conventions, ships are to be constructed with an immediate reduction in greenhouse gas (GHG) emissions of 15%, then 20% by 2020, and 30% by 2025 (Lee & Nam, 2017). The reason is that the enormous scale of the industry means that it is nevertheless a significant contributor to the world's total greenhouse gas emissions, which is around 3% of total global CO2 emissions (ICS, n.d.). Therefore, International organizations continue to tighten regulations on ship emissions toward the realization of their ambitions, which will further strengthen the maritime sector as the friendliest mode of transportation.

Table 3.1: Results of literature review (Nusa and Kodak, 2023).

Title of study	Authors	Keywords
"A comparative CO_2 emissions analysis and mitigation strategies of short-sea shipping and road transport in the Marmara Region"	Ulker et al., 2021	"CO_2 emissions; road transport; short-sea transport; Sea of Marmara"
"Road and Maritime Transport Environmental Performance: Short SeaShipping Vs Road Transport"	Castells et al., 2012	"Maritime Transport, Short Sea Shipping, Road Transport, Environmental performance"
"Emphasis on Occupancy Rates in Carbon Emission Comparison for Maritime and Road Passenger Transportation Modes"	Dujmovic et al., 2022	"Carbon emissions; occupancy rates; passenger mobility; transportation mode choice; maritime transportation; road transportation"
"*Iso-emission map*: A proposal to compare the environmental friendliness of short sea shipping *vs* road transport"	Vallejo-Pinto et al., 2019	"Greenhouse gas emissions Iso-emission map Motorway of the sea Road transport Short sea shipping"
"Environmental Comparison of Different Transport Modes"	Skrucany el al., 2018	"Energy consumption; GHG production; road transport; rail transport water transport"
"Mode shift as a measure to reduce greenhouse emissions"	Nelldal el al., 2012	"Mode shift; greenhouse gas; GHG; rail; passenger transport; freight transport; infrastructure investment; EC white paper."

Table 3.1: Results of literature review (continue) (Nusa and Kodak, 2023).

Title of study	Authors	Keywords
“Comparison of Inland Ship Emission Results from a Real-World Test and an AIS-Based Model”	Jiang el al., 2021	“Inland ship emission; AIS-based emission model; real-world test; PEMS”
“Driving Factors behind Energy-Related Carbon Emissions in the U.S. Road Transport Sector: A Decomposition Analysis”	Jiang et al., 2022	“Carbon emissions; carbon neutrality; renewable energy; electric vehicles”
“Greenhouse gas emissions from global shipping, 2013-2015”	Olmer et al., 2017	-
“Reducing Greenhouse Gas Emissions from Ships through Analyzing Marginal Abatement Cost (MAC) Curves”	Tien, 2017	“Greenhouse gas emission; marginal abatement cost; climate changes.”
“The impacts of CO2 emissions from maritime transport on the environment and climate change”	Tatar et al., 2018	“Climate Change CO2 Emissions Environment Maritime Transport”
“The Role of International Maritime Traffic on PM10 Pollutants in the Strait of Istanbul (Bosphorus)”	Kodak, 2022	“Ship Emissions; PM10; Strait of Istanbul; Maritime Transportation”

Table 3.1: Results of literature review (continue) (Nusa and Kodak, 2023).

Title of study	**Authors**	**Keywords**
“Impact of a Telemedicine Program on the Reduction in the Emission of Atmospheric Pollutants and Journeys by Road”	Vidal-Alaball et al., 2019	“Telemedicine; carbon dioxide; air pollutants; vehicle emissions; primary care”
“Impact of maritime transport emissions on coastal air quality in Europe”	Viana et al., 2014	“Source apportionment Vessels; Mitigation strategies; Harbour operations; Shore power”
“Quantification of carbon emissions of the transport service sector in China by using streamlined life cycle assessment”	Duan et al., 2015	“Transport service sector; Carbon dioxide emissions; Streamlined life cycle assessment; China”
“Quantifying Emissions in the European Maritime Sector”	Istrate et al.,2022	“Technical reports; Energy and transport; Environment and climate change”
“Review of the studies on emission evaluation approaches for operating vehicles”	Lyu et al., 2021	“Traffic engineering; Operating vehicles; Vehicle emissions; Emission measurements; Emission models; Vehicle emission evaluation”

Table 3.1: Results of literature review (continue) (Nusa and Kodak, 2023).

Title of study	Authors	Keywords
“Measurements of the Emissions of a “Golden” Vehicle at Seven Laboratories with Portable Emission Measurement Systems (PEMS)”	Giechaskiel, et al., 2021	“Vehicle emissions; real-driving emissions (RDE); portable emissions measurement systems (PEMS); validation test; round robin; repeatability; reproducibility”
“A review of trends and drivers of greenhouse gas emissions by sector from 1990 to 2018”	Lamb et al., 2021	“Greenhouse gas emissions; energy systems; industry; buildings; transport; AFOLU; trends and drivers”
“Prioritizing Environmental Justice and Equality: Diesel Emissions in Southern California”	Marshall et al., 2014	-
“Intermediate Volatility Organic Compound Emissions from a Large Cargo Vessel Operated under Real-World Conditions”	Huang et al., 2018	-
“Primary Particulate Matter Emitted from Heavy Fuel and Diesel Oil Combustion in a Typical Container Ship: Characteristics and Toxicity”	Wu et al., 2018	-

Table 3.1: Results of literature review (continue) (Nusa and Kodak, 2023).

"Numerical Modeling of Air Pollutants and Greenhouse Gases Emissions in Intermodal Transport Chains"	Ramalho et al., 2021	"Freight transport emissions; short sea shipping emissions; modal shift; greenhouse gas emissions; sustainable transport"
"A review on air emissions assessment: Transportation"	Fan et at., 2018	"Transportation; Greenhouse gas; Air pollutants; Emissions assessment; Transportation mode choice"
"A Study on Emissions from Drayage Trucks in the Port City-Focusing on the Port of Incheon"	Lee et al., 2019	"Urban freight transport; drayage truck; port city; emission; sustainability"
"EU shipping's climate record Maritime CO2 emissions and real-world ship efficiency performance"	Abbasov et al., 2019	-
"A freight transport demand, energy and emission model with technological choices"	Yana et al., 2020	"Freight transport; CO2 emission; Energy consumption; Carbon tax; CO2 emission performance standard; goods vehicle"
"The comparative CO2 efficiency of short sea container transport"	Svindland et al., 2019	"Short sea shipping; environmental sustainability; emission; cost efficiency"

Table 3.1: Results of literature review (continue) (Nusa and Kodak, 2023).

Title of study	Authors	Keywords
"Easy Ride: why the EU truck CO2 targets are unfit for the 2020s"	Suzan., 2021	"Transport & Environment"
"A review on regulations, current status, effects and reduction strategies of emissions for marine diesel engines"	Ni et al., 2022	"Marine diesel engines; Emissions; Alternative fuel; Exhaust gas after-treatment"
"State-of-the-art technologies, measures, and potential for reducing GHG emissions from shipping – A review"	Bouman et al., 2017	"Maritime transport; Shipping and the environment; Greenhouse gases; Abatement options; Emission reductions"
"Comparative Analysis of Long-Distance Transportation with the Example of Sea and Rail Transport"	Neumann., 2021	"Maritime transportation; railway transportation; multi-criteria analysis"
"Modelling of Ship Originated Exhaust Gas Emissions in the Strait of Istanbul (Bosphorus)"	Bayırhan et. al, 2019	"The Strait of Istanbul, Emission, Air pollution, Vessel Traffic, CO2"

Table 3.1: Results of literature review (continue) (Nusa and Kodak, 2023).

Title of study	Authors	Keywords
“Factors affecting the emission of pollutants in different types of transportation: A literature review”	Aminzadegan et al., 2022	“Greenhouse gases; Emission; Railway transport; Road transport; Marine transport; Air transport”
“Natural gas fuel and greenhouse gas emissions in trucks and ships”	Speirs et al., 2020	“Ships; trucks; natural gas; greenhouse gas; emissions”
“Speed correlation and emission of truck vehicles on dynamic conditions”	Lutfie et al., 2018	-
“Impact of congestion on greenhouse gas emissions for road transport in Mumbai metropolitan region”	Bharadwaj et al., 2017	“Mumbai; greenhouse gas emissions, traffic congestion”
“Simulation of Air Pollutants Emission by Trucks and Their Health Effects”	Posada-Henao et al., 2022	“Emissions; trucks; off-hours; human health; Acute Respiratory Infections (ARI)”
“How and why we travel – Mobility demand and emissions from passenger transport”	O'Riordan et al., 2022	-

Table 3.1: Results of literature review (continue) (Nusa and Kodak, 2023).

Title of study	Authors	Keywords
"European road transport policy assessment: a case study for Germany"	Schulthof et al., 2022	"Transport policy; Evaluation; Environmental policy instruments; Road transportation; Regulation; Policy assessment"
"Health benefits of decreases in on-road transportation emissions in the United States from 2008 to 2017"	Choma et al., 2021	"Particulate matter; transportation; air pollution; public health; climate change"
"Emissions from a Modern Euro 6d Diesel Plug-In Hybrid"	Selleri et al., 2022	"Regulated pollutants; unregulated pollutants; greenhouse gas emissions; on-road vehicle testing; laboratory vehicle testing"
"CO2 Emissions and The Transport Sector in Malaysia"	Solaymani., 2022	"Transport CO2 emissions; energy intensity; urbanization, ARDL; impulse response; Environmental Kuznets Curve"
"The emission reduction potential of electric transport modes in Finland"	Jenu et al., 2021	"Modal shift; electric transport modes; electric aviation; greenhouse gas emissions; travel time"

Table 3.1: Results of literature review (continue) (Nusa and Kodak, 2023).

Title of study	Authors	Keywords
“The environmental impacts of cars, explained”	National Geographic Staff 2019	-
“The potential role of hydrogen as a sustainable transportation fuel to combat global warming”	Acar et al., 2020	“Hydrogen; Fuel; Sustainability; Internal combustion engine; Transportation; Energy”
“An overview on global warming in Southeast Asia: CO2 emission status, efforts done, and barriers”	Lee et al., 2013	“Southeast Asia; Global warming; Carbon dioxide; ASEAN”
“Modal shift from road haulage to short sea shipping: a systematic literature review and research directions”	Raza et al., 2020	“Modal shift; freight transport; road haulage; short sea shipping (SSS); literature review; research directions”
“Analysis of Modal Shift to Support MRT-Based Urban Transportation in Jakarta”	Febriani et al., 2019	-
“Joint Model of Sustainable Mode Choice for Commute, Shift Potential and Alternative Mode Chosen”	Ambi Ramakrishnan et al., 2021	-

Table 3.1: Results of literature review (continue) (Nusa and Kodak, 2023).

Title of study	Authors	Keywords
"How to make modal shift from road to rail possible in the European transport market, as aspired to in the EU Transport White Paper 2011"	Islam et al., 2016	"Rail freight; Customer requirements; Improvements; Modal shift; White paper 2011; 2050; Europe"
"A comparative analysis of COx emissions by road and sea transport"	Srinivasan., et al 2017	"Comparative; Green house; Emission & Logistics."
"Measuring in-use ship emissions with international and U.S. federal methods"	Sindhuja et al., 2013	-

Table 3.2 below presents a comparison between road transport and maritime transport, highlighting several characteristics-feature, weaknesses, and strengths.

Table 3.2: Comparative analysis of road and maritime transport (Nusa and Kodak, 2023).

Parameters	Road Transport	Maritime Transport
Distance	Suitable for short	Suitable for long distance
Door-to-door delivery	It promotes door-to-door services	Due to the limitation imposed by Coastline door-to-door delivery is hindered
Cargo capacity	Limited to truck size, government regulation, and available traction	Except for container size limitation, it could support a wide range of goods across various sizes, shapes, and weights.
Hazard substance	It is not the most suitable for hazardous material	It is highly recommended for hazardous materials with a 99.99% success in delivery (Seaspace, n.d.)

Table 3.2: Comparative analysis of road and maritime transport (cont.) (Nusa and Kodak, 2023).

Cost Australian interstate freight rates, 2016)	8.38 cents per net tonne-kilometer (Bureau of Infrastructure, Transport and Regional Economics 2017)	2.90 cents per net tonne-kilometer (Bureau of Infrastructure, Transport and Regional Economics 2017)
Speed	Suitable for small goods and are usually delivered within a day	Very slow, freight could take days or weeks
Uncontrollable circumstance/limitations	It is easily affected by weather and traffic. Container size and weight impose a drawback to trucking	Could be affected by adverse weather conditions and unavoidable delays in port. It has a vast load capacity and multiple container sizes are available

Table 3.2: Comparative analysis of road and maritime transport (cont.) (Nusa and Kodak, 2023).

Parameters	Road Transport	Maritime Transport
Loading and unloading time	This could range from a few minutes to hours depending on the size of the truck and the nature of the goods	Usually, this takes several days
International trade	Trucks move goods to and from the port, and from the warehouses. So they facilitate distribution while ensuring door-to-door delivery	Shipping is the backbone of international trade.
Carbon footprint	The European Automobile Manufacturers Association reports 56.5g/t.kg as the average CO_2 emission for heavy-duty trucks (ACEA, 2020)	They have low CO_2 emissions compared to other modes emitting between 10 to 40 grams of CO_2 per nm (Kennemer, 2020)

4. CONCLUSION

Our natural environment contains essential resources meant for the survival and sustainability of life. These resources are naturally occurring and available in abundance. In recent times, human's drive towards development and advancement in technology has guaranteed the depletion of these resources and undermined the environment's ability to sustain life. Clean air, water, natural vegetation, and wildlife are natural environmental resources under continuous attack by the present-day civilization. By burning fossil fuels to develop energy to drive the transport sector, the transportation emission footprint continues to increase over the years. Therefore, to achieve the ambition of international organizations the resources used for transportation must be significantly reduced to a point where environmental sustainability is guaranteed and resources are utilized in a manner that does not compromise the needs of the future generation.

Transportation helps to drive business and promote civilization. However, it is a major contributor to anthropogenic GHG. There is therefore an urgent need to decarbonize the transport sector.

This study uses the PRISMA method to evaluate and review emissions from the maritime and road transport sector. The review compares and summarize scientific publications on transport emissions between 2012 and 2022 by reviewing journal publications during this period. As a result of the literature review, 62 scientific publications were accessed. From the review, maritime transportation could provide leading steps towards reduction of transportation GHG. If maritime transport could be operated as close to 100 percent occupancy rate, it will provide a valid means to reduce transportation GHG when used for significantly long distance and for large volume of freight. On the other hand, public bus provides a sustainable means of transport over short and medium distance even with a moderate occupancy rate. Again, if we consider the CO2 emission along with the load factor and energy requirement between maritime and road transport. The review shows that even at 0%, 50% and 100% backhaul load factors, maritime transport appears to be more superior to road transport. Although, it is difficult to make a direct comparison of maritime and road transport since they differ in capacity and volume of freight transported. Nevertheless, they could be compared using their emission rate or base on the gram of CO_2 emitted per tonne of freight per kilometer traveled. It difficult to isolate a particular mode for excellent environmental performance, international trade, door-to-door delivery, timely delivery and sustainability. Maritime transport is the backbone of international trade and the most ecofriendly. It emits the least tonne of CO_2 per unit load transported per unit distance of travelled. In other words, it has the least gram of CO_2 per tonne-kilometre (gCO_2/tkm). Nevertheless, it significantly slow, not suitable for short distance and capital intensive. Road transport on the other hand offers speedy transportation of moderate volume of freight over short distance. Since maritime transport is limited to the sea and ocean, road transport is essential to move freight from the factory to the port and from the port the warehouse. Therefore, it is quite difficult to isolate one for the other especially in light of their role in international trade. Therefore, there must be infrastructural development that supports continuous mode shift.

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