Climate Change and Seaports: Analysing the Contributing Factor, Impact and Mitigation Plan.

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Climate change and seaports: analysing the coalescence on causal nexus and adaptation strategy through science mapping procedures

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Abstract

Purpose - Climate change (CC) and seaports are closely related, as both have significant impacts on each other. This research aims to establish the following: (1) factors from seaports; (2) impact of CC; and (3) strategies to overcome CC. CC causes severe weather-related impacts on seaports, leading to disruptions that may induce severe economic losses; whereas seaports act as contributors to exacerbating these climate events. On the other hand, global trade has significantly increased and is forecast to continue growing in the near future. This raises a debate on contributing factors and adaptation features.

Design/methodology/approach - This research adopted a bibliometric analysis to identify the factors from the seaport, the impact of the CC and the strategies to overcome the CC.

Findings - The discussion in this work included nine major factors from seaports that contribute to CC themes, ten major themes on the impact of CC on seaports, and nine major themes of strategies to overcome CC impacts. Based on the five major factors, greenhouse gas (GHG) emissions from ships are deemed a major contributor to CC. Heavy dependency on fossil fuels and near-future increase in global trade will contribute further to CC. Investing in newer technologies, green energy, alternative fuel, and the Internet of Things (IoT), among others, could act as a mitigator; whereas grey infrastructures, such as breakwater, groynes, rock revetment, and others, could act as temporary solutions for providing safe navigation and protecting the seaport face. In context, mitigation provides a long-term solution, whereas adaptation provides a temporary solution due to the frequency and intensity of CC that continue to increase in every form.

Originality/value - This research has managed to close the gap between factors from the seaports that contribute to CC. Seaports heavy dependency on fossil fuels and continued contribution of GHG have been significant. Increasing global trade will further enhance the contribution. Aligning with Sustainable development with goal of achieving zero carbon emissions by 2050, it is a must for seaports to look for alternatives to mitigating the factors that have continuously contributed to CC. This research paper has highlighted a few approaches, such as green technologies, collaboration and others to guide through the transition period.

Keywords: Climate Change; Seaports, Bibliometric Analysis

1.0 Introduction

Global temperatures have been rising since the preindustrial era, and this trend is accompanied by a notable increase in the severity of weather patterns, leading to a noticeable shift in the frequency and intensity of extreme events occurring at a faster pace (Jebbad et al., 2022). According to the Intergovernmental Panel on Climate Change (Masson-Delmotte et al., 2021b), 95 per cent of the emissions contributing to the increasing temperature trend are the result of anthropogenic activities. Furthermore, it is observed that CC and climate variability—natural phenomena driven by seasonal fluctuations—lead to events such as floods, intense rainfall, and prolonged droughts in terms of both their intensity and frequency of occurrence (Van Der Wiel et al., 2021). Moreover, CC has caused sea level rise (SLR) due to global temperature increases, which result from the melting of ice sheets and thermal expansion (ESOTC, 2022). According to the Intergovernmental Panel on Climate Change (IPCC) report, the global mean sea level (GMSL) has increased by 0.20 metres since 1901–2018.

Seaports are vital hubs for global trade and commerce, but they are not immune to the far-reaching effects of CC due to their vulnerable coastal locations. They face extreme events such as storm surges, coastal inundation, tropical storms, strong winds, and flooding (Vitousek et al., 2017; Kouakou et al., 2023; Chapapría & Peris, 2021). Additionally, seaport-related activities contribute to CC, as they often result in pollution and emissions. In this context, identifying the contributing factors at seaports, understanding the impact of CC on seaports, and developing effective strategies and sustainable approaches are crucial in order to maintain seaport activities while minimising their impact on the environment. Through this research, examining the factors at seaports, understanding the impact of CC on seaports, and adopting effective strategies and sustainable approaches can pave the way for better resilience while enhancing seaport competitiveness. Proactive efforts to combat CC and address factors in the seaport industry will not only safeguard economic prosperity but also contribute to a greener and more sustainable future for generations to come.

2.0 Seaports and climate change: factors, adaptation plan and implications

Seaports are affected by CC, which manifests through rising sea levels, extreme weather events, and shifting weather patterns. Rising sea levels pose a threat to coastal seaports, increasing their vulnerability to flooding and coastal erosion. Extreme weather events, such as hurricanes and storms, can disrupt seaport operations, damage infrastructure, and result in substantial economic losses. Moreover, changing weather patterns may lead to altered shipping routes and unpredictable sea conditions, impacting seaport efficiency and safety (Poo et al., 2021). The primary causes of CC are the increasing trends of emissions and pollution accumulating in the atmosphere, acting as a blanket that traps heat and raises global temperatures. Emissions and pollution are largely determined at seaports, stemming from stationary sources, such as the electricity grid, power plants, and administrative offices, as well as mobile sources, such as ocean-going vessels, cargo-handling equipment, locomotives, and internal and external trucks (Song, 2021). In addition to these factors, global trade has been on the rise (Meng et al., 2018), with forecasts indicating further increases, reaching 80,000 billion tonne-miles by 2050 (DNV, 2021). As this trend continues to grow, so does the rate of emissions and pollution, further contributing to CC. In simple terms, CC has adverse impacts on seaports, while seaport activities have been a significant contributor to CC. Consequently, immediate action is required to address these contributing factors that can exacerbate extreme events due to CC.

The impact of CC on seaports is multi-faceted. Extreme weather events have both direct and indirect effects. The direct impact includes infrastructure damage, operational disruptions, and service interruptions. Indirect impacts extend to seaport demand, trade, and investment choices (Asariotis et al., 2017). Furthermore, seaport infrastructure, such as quays, piers, and warehouses, may require costly upgrades and modifications to withstand rising sea levels and extreme weather events. Moreover, coastal erosion can lead to land loss, necessitating seaport expansion projects. Nevertheless, increased disruptions in seaport operations due to weather-related incidents can result in delayed shipments, higher logistics costs, and potential economic consequences for seaport-dependent communities (Becker et al., 2012).

The increasing threat of CC to seaports may have a negative impact on a country's Gross Domestic Product (GDP) since seaports play a vital role in stimulating economic activity that contributes to GDP (Jouili, 2016). Additionally, rising sea levels, changes in storm patterns, and floods can cause disruptions, delays, and damage to seaport assets and infrastructure (Morris, 2020). The impact of CC has also led to the emergence of new routes, such as the Northern Sea Route (NSR), offering shorter travel distances and cost-effectiveness, which poses a threat to existing seaports (Pruyn and Van Hassel, 2022). In addition, the importance of seaports to the economic sector is undeniable. Therefore, the continuity of seaport operations must be guaranteed while ensuring any negative impact on the environment is reduced through adaptation and mitigation strategies.

The adverse impact of CC demands immediate action, involving both adaptation and mitigation options. Adaptation options primarily focus on protecting against current weather elements that could cause disruptions; these are generally short-term solutions. In contrast, mitigations involve solutions to reduce the contributing factors from seaports that could exacerbate CC events; these are typically long-term measures (Jiang et al., 2020). Mitigation options such as building resilient infrastructure that considers rising sea levels and extreme weather events are vital (Cai et al., 2021). Likewise, green infrastructure solutions, such as living shorelines and wetland restoration, can provide protective barriers and enhance environmental sustainability (Devendran et al., 2023). This mitigation option offers carbon sequestration through tree replanting and the allocation of green buffer areas (Agbelade and Onyekwelu, 2020). Additionally, green and smart ports offer the best solutions for preventing emissions originating from seaport operations and shipping (Bergqvist et al., 2018).

Seaports are considered high-energy-demanding entities, so implementing energy-efficient technologies and practises can reduce greenhouse gas emissions associated with seaport operations. Renewable energy sources, such as solar and wind power, can be integrated into port facilities to minimise carbon footprints (Chen et al., 2022; Le et al., 2021). Microgrids connected to the national grid, which offer green energy, are the best solutions to reduce energy demand and related emissions. Alternatives should be considered for machinery and vessels that heavily rely on fossil fuels, including electrification, hybrid systems, onshore power supplies, and other innovations. Developing comprehensive climate resilience plans that assess risks and vulnerabilities is essential. These plans can include emergency response measures, disaster preparedness, and business continuity strategies. These resilience plans aid in identifying the most vulnerable areas due to climate-related events. Adaptation and mitigation should be integral parts of this plan, as both are crucial in protecting the well-being of seaports (León-Mateos et al., 2021). Furthermore, seaport resilience can determine success by building trust with clients, mainly by providing safety measures. Moreover, a resilience plan helps the seaport be prepared for all eventualities related to climate events, avoiding service disruptions or economic losses (Laxe et al., 2012; Proag, 2014; Reggiani et al., 2015; Wang et al., 2020b).

Cooperation among port authorities, shipping companies, and relevant stakeholders is critical for sharing knowledge and resources to collectively tackle CC challenges (Ryan-Henry & Becker, 2020). Economic disparities between developing and developed countries have created significant gaps. These disparities can hinder the formation of a consensus among countries on addressing CC impacts and mitigation approaches. Furthermore, cooperation and collaborative efforts are necessary to mitigate factors originating from seaports, as the findings shared may involve significant investments that could potentially burden developing countries.

3.0 Methodological structure

VOS viewer software has been the primary data mining tool for the bibliometric analysis technique. The content analysis was used to extract the data mining results, which were subsequently coded to archive the paper's goal.

3.1 Bibliometric Analysis

Numerous disciplines, including biology, social science, education, and mathematics, have made extensive use of bibliometric analysis (Selvaduray et al., 2023). The maritime industry has greatly embraced this innovative kind of literature review study (Munim et al., 2020). The primary advantage of bibliometric analysis is its ability to present the findings in statistical and numerical forms. A bibliometric analysis is a type of literature review approach that can be carried out by statistically and quantitatively analysing published studies, according to Selvaduray et al. (2022). Numerous analyses, including citation and network analyses and descriptive analyses of authors, journals, universities, nations, and keywords, can be carried out. Bibliometric analysis is more dependable and consistent than other literature reviews. According to Selvaduray et al. (2023), bibliometric analysis consists of nine steps:

3.1.1 Step 1: Define the scope of research

Along with other sectors including the medical, manufacturing, and information technology industries, the maritime business is constantly expanding. The maritime industry is divided into numerous categories, including shipbuilding, dry ports, and marine transportation (Gil et al., 2020). In order to obtain a thorough result from a bibliometric analysis, it is primarily necessary to narrow down and specify the sub-sector. One of the sectors in the globe that is growing the fastest is maritime transportation, which also contributes significantly to the economies of maritime nations (Selvaduray et al., 2022).

3.1.2 Step 2: Determine the search database platform

According to De Oliveira et al. (2019), Scopus is a platform for scientific research that offers dependable databases and a good assortment of search criteria. It is also one of the largest databases of abstracts and citations of peer-reviewed literature, containing over 22,800 articles from 5000 different publishers worldwide. Scopus covers a wide range of topics, including information technology, education, agriculture, social sciences, and biological sciences. Being one of the biggest databases of peer-reviewed literature with extensive coverage of academic publications, it is widely used as a database for literature searches (Bolbot et al., 2020). Furthermore, Scopus is the world's largest scientific database and the most complete, reliable, and popular database for bibliometric research; it is suitable for any kind of study. According to Da Silva et al. (2018), it could be more consistent to pull scientific data from multiple scientific platforms when conducting a bibliometric study. This work has integrated the bibliometric analysis with two distinct databases, Scopus and Web of Science, in order to obtain thorough and meaningful results. The primary reasons that led to the integration of WoS and Scopus were that they are both widely utilised in interdisciplinary research, have sizable collections of relevant scientific publications, and offer a range of tools for scientific data mining (De Oliveira et al., 2019; Munim et al., 2020; Fu et al., 2021).

3.1.3 Step 3: Explore the search criteria

Typically, the paper's research objectives serve as the basis for selecting the search criteria. The three primary goals of this article are to identify the contributing causes, analyse the effects, and investigate the available tactics for overcoming CC. The search string tactics applied to the WoS and Scopus databases are displayed in Table 1.

Table 1: Search string strategies used on the Scopus

No	Keywords Search					No of Articles (Scopus)
1.	Maritime	AND	Climate Change	AND	Factors	100
2.	Maritime	AND	Climate Change	AND	Impact	262
3.	Maritime	AND	Climate Change	AND	Strategy	87
Total						449
After remove duplicates						368

3.1.4 Step 4: Define, Review and Save

Given the near impossibility of reviewing every item published in the past, the researcher ought to choose a timeframe for review (Cao et al., 2023). 15 years of data is enough, according to Fu et al. (2021), for assessing research data and tracking the advancement of the field. According to Cao et al. (2023), conference papers, books, chapters, and book series must be excluded in order to preserve the calibre of the final product. Meyers et al. (2021) restricted the search to English-language publications solely to prevent ambiguity and the associated difficulties associated with translation. Table 2 provides a summary of the inclusion criteria used in this investigation.

Table2: Summary of inclusion criteria

No.	Inclusion Criteria	
1.	Access Type	All
2.	Years of Publications	10 Years (2014–2023)
3.	Subject Areas	Social Science, Business and Management, Environmental Science, Earth, and Planetary Science
4.	Document Type	Article
5.	Publication Stage	Final
6.	Source Type	Journals from Scopus
7.	Language	English

3.1.5 Step 5: Export the data

Numerous file formats are offered as export alternatives for scientific systems. Comma-separated values (CSV) files are the ideal export file format since they enable uninterrupted bibliometric data analysis in VOSviewer (De Oliveira et al., 2019).

3.1.6 Step 6: Import the Data

Researchers that are studying bibliometric analysis are strongly encouraged to use VOSviewer, an open-source, free licence programme. Better accessibility is one of VOSviewer's benefits, which makes managing the scientific database analysis easier (VOS, 2022).

3.1.7 Step 7: Bibliometric Data Analysis

The results of the bibliometric analysis in this work allow the researcher to explore previously uncharted territory, like climate studies, and provide more detailed information. According to De Oliveira et al. (2019), Jeevan et al. (2021), Selvaduray et al. (2022), authors, articles, countries, keywords, evolution of publishing, and institutions are the six primary categories of bibliometric analyses that this paper employed. The sort of bibliometric data analysis method employed in this paper is described in Table 3 below.

Table 3: Type of bibliometric data analysis

No.	Type of Bibliometric Data Analysis	Explanation
1.	Evolution of publication	Evolution of publication enables researchers to more clearly see how each group has contributed to the advancement of the state-of-the-art over the research many years.
2.	Keywords	Keywords is to identify the primary research topics of various scientific research fields, making them one of the most crucial parts of any research paper. They offer a concise representation of a text that lets readers anticipate its content.
3.	Countries	Countries based research articles suggests research collaboration and exemplifies the exchange of scientific information among various entities.
4.	Authors	Author analysis determine the experts in the field who continuously publishing papers.
5.	Articles	Focused on answering the goal of this paper. Which are to identify the difference between the role of seaport museum and maritime museum and explore the important of seaport museum for the seaport industry.
6.	Institutions	Clearly justified the institution who were continuous carrying out research in the current field and able to exchange of scientific knowledge and collaboration between various entities.

Source: Selvaduray et al. (2022)

3.1.8 Step 8: Analyse and Review the Selected Articles

This step refers to the archive of the two main objectives by using content analysis for the coding process. This process was conducted carefully, and it is deemed significant, as the data are not explicitly noted in the text and these gaps are more difficult to spot. Therefore, it is crucial to consider the experience and familiarity of the researcher with the subject in order to identify these implicit gaps. This is because, researchers with more experience in the maritime field will be able to understand the content more precisely.

3.1.9 Step 9: Conclusion

Finally, it is important to mention that the new complete framework and conclusions acquired through the use of bibliometric analysis will be justified. The bibliometric analysis methods employed in this paper is illustrated in Figure 1.

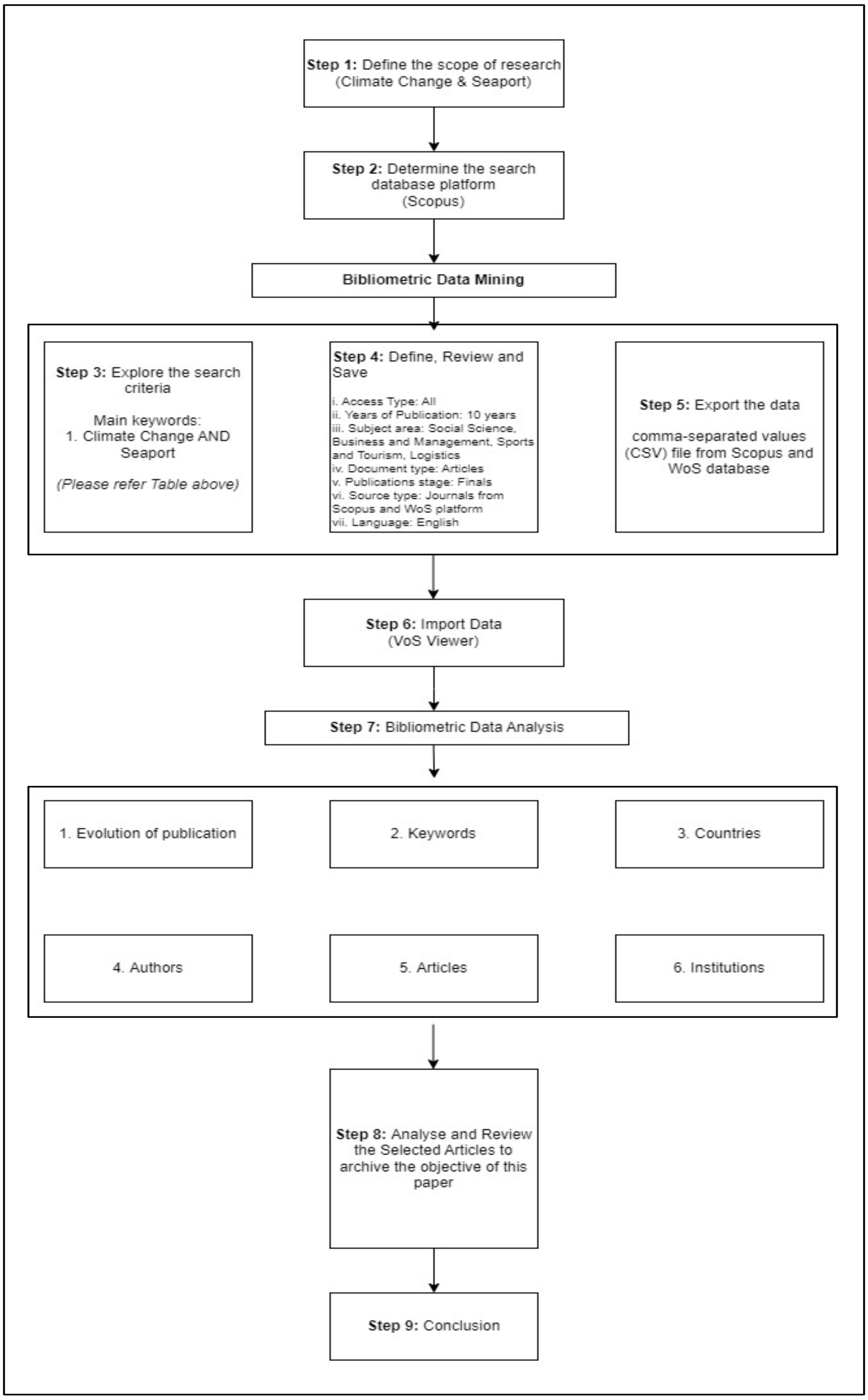

Figure 1: Flow chart of the bibliometric analysis

Source: Adapted from Selvaduray et al. (2022)

4.0 Results

The findings indicate that the Scopus database had 368 journals. The results of the bibliometric data analysis were covered in subsections 4.1–4.7. These included an evolution of the publications, keywords, countries, authors, articles, and institutions, as well as the analysis's findings for examining the chosen articles from the Scopus and WoS databases in order to archive the goal.

4.1 Evolution of Publications

Comparing the seaports and CC publication timeline evolution to that of marine transportation, Figure 2 below illustrates how deficient it is. The findings unequivocally demonstrate the need to identify a significant gap in the literature on maritime and climate change.

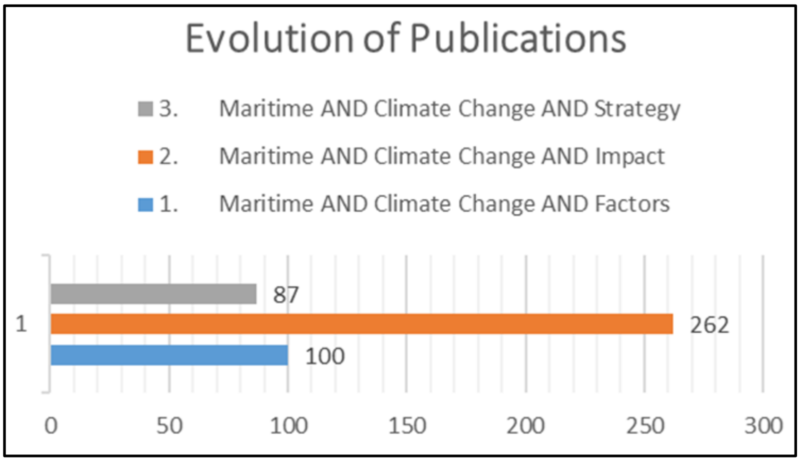

Figure 2: Evolution of publication on seaports and climate change

4.2 Keywords in the Scopus databases

The most popular keyword, as shown in Figure 3, was "Climate Change." This is because the maritime sector continues to be a significant source of revenue both domestically and internationally. Future growth is possible for maritime transportation, a subsector of the transportation industry. It is evident from Figure 3 that studies on the maritime CC industry have started. It might thus grow into a brand-new maritime market in the future.

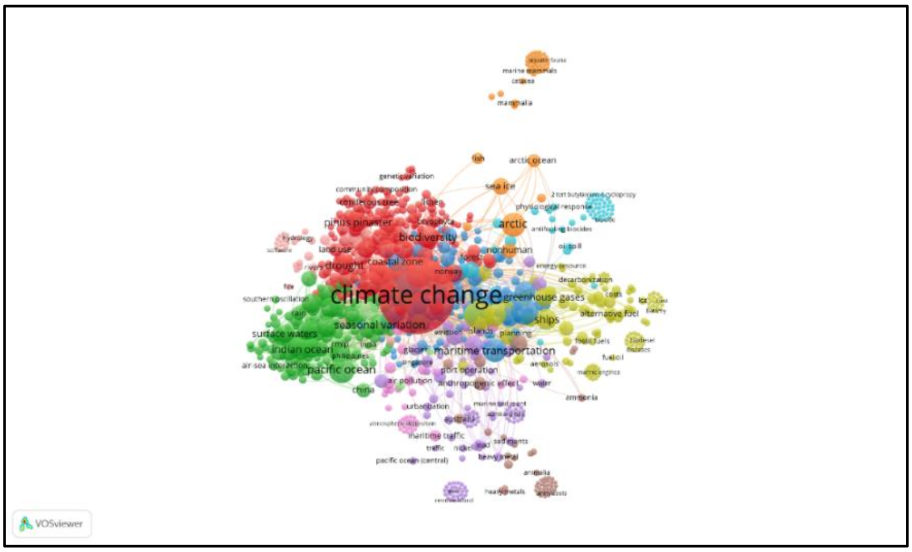

Figure 3: Word cloud analysis on climate change

4.3 Countries in the Scopus databases

Figure 4 shows that the United States and the United Kingdom demonstrated the most interest in developing the maritime industry of their countries. Some other countries also conducted an equal amount of research exploring the seaport market for the future benefit of their nations. The results also indicate that not one landlocked country has taken the initiative to explore the CC in the seaport region.

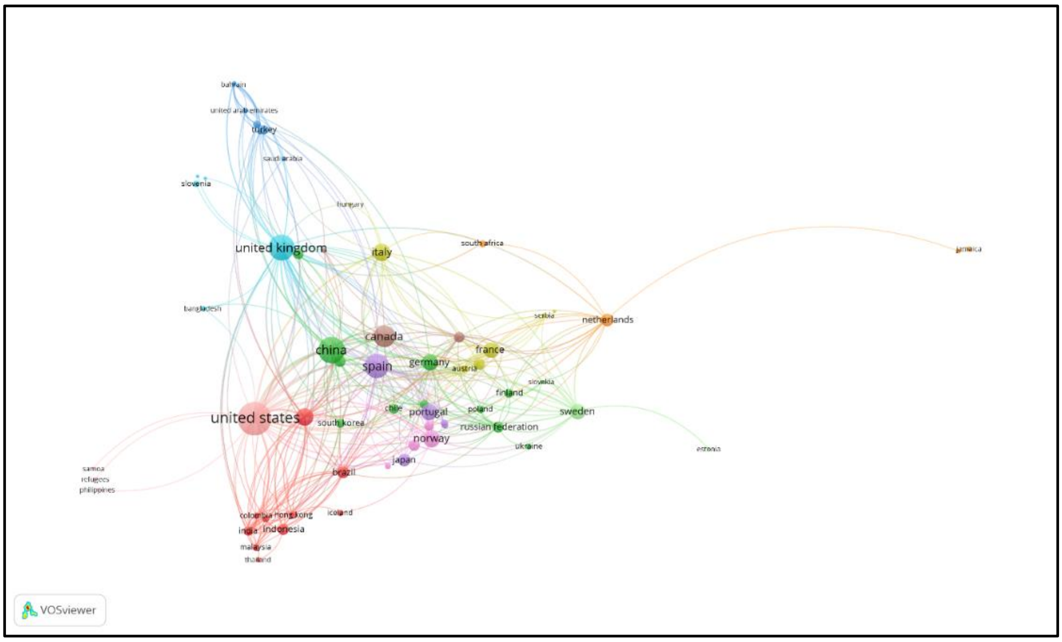

Figure 4: Countries involved in climate change research

4.4 Authors' Collaboration in the Scopus databases

Figure 5 shows the collaboration of many authors between themselves, which focused on the maritime seaport industry as having good international connections that will improve the maritime transportation sector. This collaboration indicates that existing authors have begun investigating the maritime industry and the CC.

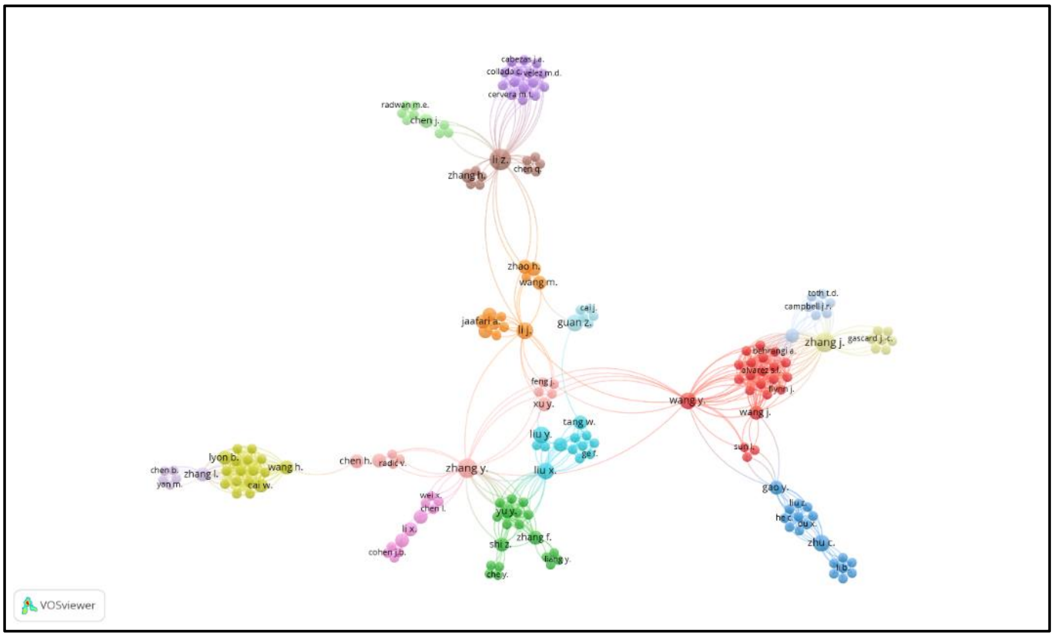

Figure 5: Authors collaboration in climate change research

4.5 Articles Published in the Scopus databases

Figure 6 reveals that the connection between publications over a 12-year period was more productive, which may indicate that more attention could be given to the maritime transportation industry in the future.

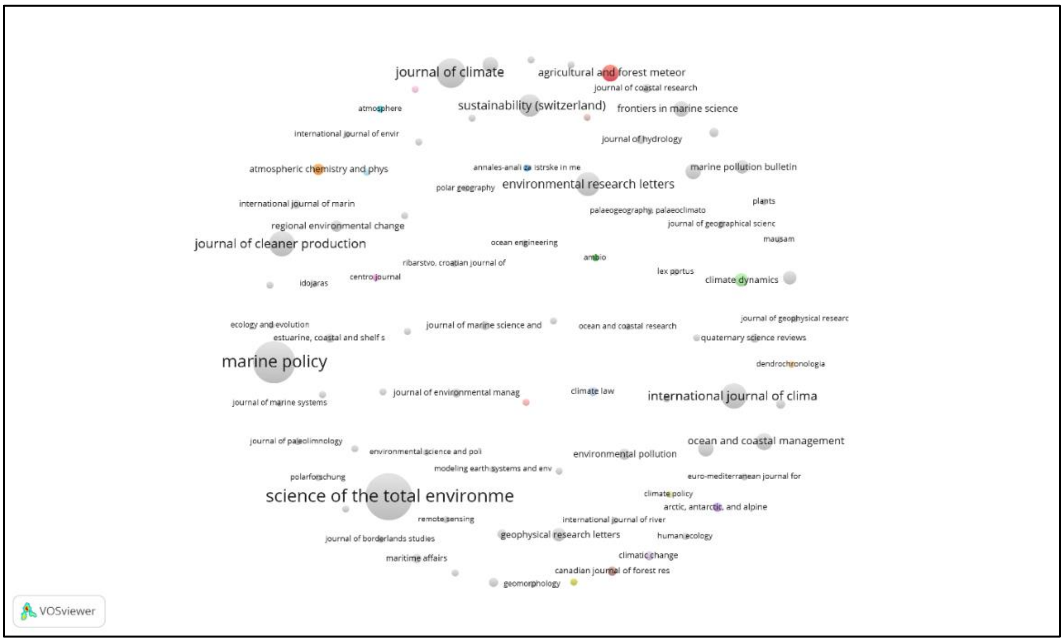

Figure 6: Scopus based journal related to climate change research

4.6 Productive Institutions in the Scopus databases

As shown in Figure 7, the respective institutes have shown an interest in furthering their research on maritime transportation, as the seaport market will contribute just as much to the national GDP as the other sectors. Governments could also provide institutions that intend to explore the new maritime market segments with incentives. Lastly, researchers who have begun examining the maritime industry could seek advice or consult with experts from the institution, as the views and details gained from the institution would be much more significant and reliable.

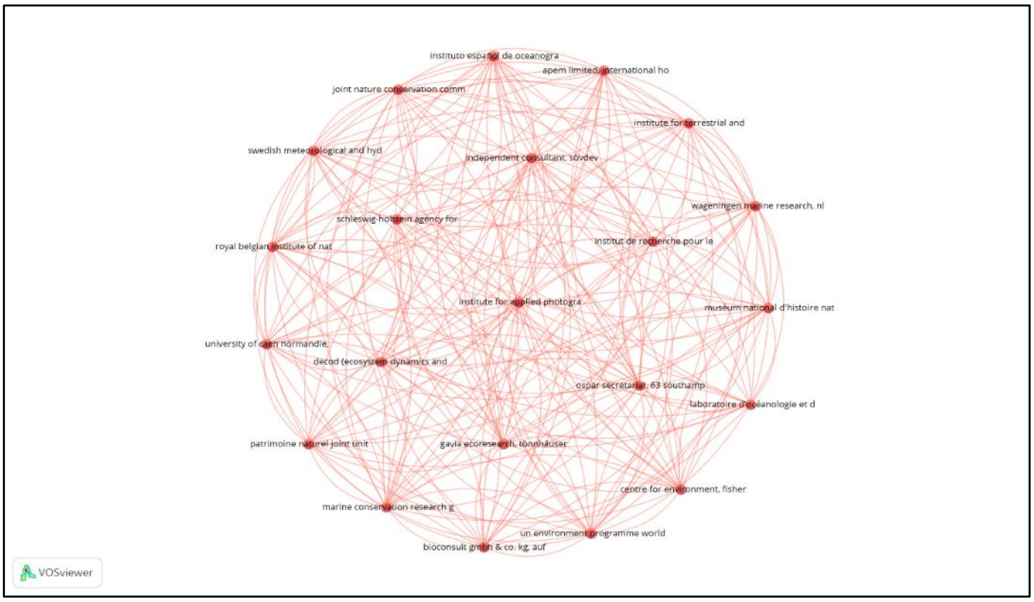

Figure 7: involvement of global institutes on climate change research

4.7 Influencing Factors of Climate Change from the seaport perspective

Human activities or anthropogenic emissions have been known to contribute to the rising global temperature, which consequently led to CC. It was reported that human-induced warming has reached 1.1°C above pre-industrial levels (Agarwal et al., 2022). Emissions, primarily from fossil fuel combustion and coal refineries, have significantly contributed to global warming. While greenhouse gases (GHGs) are produced naturally and by human activities, the current global warming trend indicates that 95 per cent of GHGs originate from anthropogenic sources (Masson-Delmotte et al., 2021a; Papić et al., 2017).

The increasing concentration of GHGs leads to changes in the global composition and alters the chemistry of the atmosphere, resulting in CC in the form of extreme events (Lin et al., 2020). Furthermore, the imbalance in Earth’s radiation balance is caused by the increased concentration of GHGs that resulted from anthropogenic activities (Gao et al., 2017). These GHGs act as a blanket, trapping heat and causing a rise in global temperature, which leads to the melting of glaciers and ice sheets, subsequently raising sea levels. Anthropogenic activities, such as large-scale reclamation, pollutant discharge, and overfishing, have detrimental impacts, thus causing instability in biodiversity and ecosystems (Cai et al., 2021).

Meanwhile, the melting of ice sheets has led to the discovery of new shipping routes, such as the Northern Sea Route (NSR) (Brigham et al., 2022). These routes offer fuel and cost savings due to reduced cargo travel time. However, as trade increases, these routes also contribute to increased GHG emissions. Ships are well-known consumers of fossil fuels, leading to GHG emissions (Camargo-Diaz et al., 2022; Schlanger, 2018). The usage of heavy fuel oil increased by 75 per cent from 2015 to 2019 (Comer et al., 2020), and particulate matter known as black carbon (Romppanen, 2018) also shows an increasing trend. These black carbons tend to float and settle on Arctic ice, reducing surface albedo and contributing to ice sheet melting (Strawa et al., 2020). Moreover, shipping emissions increased from 2.6 per cent in 2015 to 3 per cent in 2020 as a global emission contributor despite improvements in port operations and ship efficiency. These shipping emissions will continue to increase in the near future due to economic growth and increasing trade value (Olmer et al., 2017; Faber et al, 2020; Dobson et al., 2020; Zhang et al., 2017; Kanchiralla et al., 2022).

In addition, inland waterways contribute to emissions, which are noticeable locally (Savu et al., 2022). Moreover, these emissions are forecast to increase from 50 per cent in 2012 to 250 per cent in 2050, potentially leading to disastrous environmental impacts (Olmer et al., 2017). In the context of seaports, shipping is a major contributor to emissions during berthing for loading and unloading processes, with 60 to 80 per cent of GHG emissions produced during this phase (Styhre et al., 2017). This is because ships run auxiliary engines that burn fossil fuels, releasing GHGs such as nitrogen oxide, sulphur oxide, and particulate matter, resulting in higher emissions. These emissions worsen as ship calls increase, affecting the health of nearby communities (Radwan et al., 2019). Moreover, emissions released during berthing are considered to be ten times higher than those from seaport activities (Gibbs et al., 2014). For example, in Shanghai, China, one of the busiest containerised seaports, 11 per cent of emissions were nitrogen oxide, 12.4 per cent were sulphur oxide, and 5.6 per cent were particulate matter (Chen et al., 2019).

According to the International Seaport Association, ship operations at seaports are responsible for over 70 per cent of voyage emissions (Cullinane et al., 2019; Bakir et al., 2022). As trading activities continue to increase, so does the emission rate from the shipping industry. The International Maritime Organisation (IMO) reported a tremendous increase in GHG emissions, rising from 870 million tonnes in 2007 to 977 million tonnes in 2012 and reaching 1076 million tonnes in 2018 (Buhaug et al., 2009; Faber et al., 2020). Additionally, services connected to passenger and cargo transportation at seaports transport over 20 per cent of global waste discharged into the water (Hoang et al., 2022; Gössling et al., 2021). Furthermore, port operations, business activities, and seaport usage for commerce generate significant amounts of waste (Chen et al., 2022). These transportation operations contribute to GHG emissions, wastewater, and solid waste, resulting in detrimental impacts on the environment and ecosystems (Nguyen et al., 2022; Butt, 2007). Activities related to ship operation and equipment supporting ship operation, such as dredging, maintenance of navigational channels, anchorage, transshipment zones, storm shelters, and hydropower plant dredging at wharves, have negative effects on water, air, and marine environments (Drosińska-Komor et al., 2022; Pham et al., 2020).

On the other hand, the industry continues to depend on fossil fuels although shipping is regarded as the least energy-intensive method of moving goods (Wan et al., 2018). This efficiency is evident, as transporting 1 tonne of cargo over 1 km using maritime transport emits only 3 g of emissions, whereas road transport and aviation emit 60 g and 560 g, respectively (Brouer et al., 2017). Being a smaller contributor compared to other civil services, the shipping industry is projected to increase and could result in 19 per cent of global emissions if proper countermeasures are not taken (Gallo et al., 2020). Additionally, the IMO has projected that GHG emissions could increase by up to 250 per cent by 2050 due to economic growth and the increasing volume of global trade, growing at a rate of 3 per cent annually until 2050 (Ezinna et al., 2021). Furthermore, the oversupply of fossil fuels and a lack of technological knowledge hinder investment in alternative energy sources, preventing ecologically friendly shipping (Yeremenko, 2022). Without laws and penalties in place, GHG emissions are forecast to increase by 150 to 250 per cent compared to 2007 due to increased trade (Buhaug et al., 2009). Globally, seaports' reliance on coal power energy plants has been a significant contributor to GHG emissions in addition to seaport operations, ships, and dredging activities (Hall, 2010).

Thus, the seaport has various ways of affecting and contributing to accelerating the CC impacts, as most of the seaport activities rely on fossil fuels and coal as sources of energy. Even though policies and regulations are in place, emission rates continue to rise. Eventually, this leads to systemic bias in achieving zero carbon resolution by 2050. On the other hand, shipping activities have been heavily dependent on fossil fuels and emitting GHG while voyaging and several studies show that shipping emissions are subjected to heavy GHG emissions during berthing activities. This stresses the critical importance of implementing measures to curb emissions and mitigate the environmental impact of seaports on CC. Furthermore, investment in alternative energy sources and the development of ecologically friendly shipping practises will deviate from the impact of CC and its consequences.

Table 4.0: Factor from seaport that contribute to climate change

MAIN THEMES	SUB-THEMES	REFERENCE
Impact of Land Activities	Land reclamation for seaport extension	Cai et al., 2021
Exploration and Utilization of NSR	Increased utilization of new shipping routes, Such as the Northern Sea Route (NSR)	Brigham et al., 2022
GHG Emissions from Ships	Increased GHG emissions from ships and usage of heavy fuel oil	Cullinane et al., 2019; Baker et al., 2022; Buhaug et al., 2009; Drosińska-Komor et al., 2022; Pham et al., 2020; Gallo et al., 2020: Chen et al., 2019; Styhre et al., 2017; Camargo-Diaz et al., 2022; Schlanger, 2018; Comer et al., 2020; Olmer et al., 2017; Faber et al., 2020; Dobson et al., 2020; Zhang et al., 2017; Kanchiralla et al., 2022; Savu et al., 2022; Ezinna et al., 2021; Prevention of air pollution from ships, 2009
	Rising shipping emissions despite port efficiency improvements	
	Inland waterways as emission contributors	
	Ships responsible for over 70% of voyage emissions at seaports	
	Tremendous increase in GHG emissions from shipping	
	Impact of ship operations and equipment on the environment	
	Projected increase in GHG emissions from shipping due to economic growth and global trade	
	Shipping industry projected to increase and potentially contribute to 19% of global emissions	
Seaport Operations and Berthing Activities	High emissions during berthing due to auxiliary engines	Radwan et al., 2019; Gibbs et al., 2014; Nižetić et al., 2022; Gössling et al., 2021; Chen et al., 2022; Ezinna et al., 2021
	Severe emissions during berthing compared to seaport activities	
	Transport of over 20% of global waste by services connected to passenger and cargo transportation	
	Port operations and commerce generating significant waste and emissions	
Heavy Fossil Fuel Dependencies	Over supply of fossil fuels and lack of investment in alternative energy sources	Yeremenko, 2022; Wan et al., 2018; Hall, 2010
	Seaports' reliance on coal power energy plants as significant contributors to GHG emissions	

4.8 Impacts of climate change on seaports

The CC is the result of rising global temperatures, which have significantly altered the weather system. The occurrence and intensity of extreme weather events pose a definite threat to many economic sectors, especially in coastal regions (Pavlović et al., 2020). The melting of ice sheets and thermal expansion have contributed to an increase in sea levels (Georgakakos et al., 2014). Rising sea levels and extreme events, such as flooding, strong winds (gusting), storm surges, tidal inundation, and drought, have detrimental impacts on coastal regions (Cai et al., 2021). Similarly, the intensity of weather events has significantly increased, with more cases of storm surges, greater tropical storm intensity, and a slower translation speed (Knutson et al., 2020; Hillebrandt-Andrade et al., 2021; Kossin et al., 2020). Furthermore, the Emergency Event Database (EM-DAT) indicates a significant increase in the number of extreme events and disasters (Poo et al., 2022). Moreover, damage caused by extreme heat has increased by eight times, whereas storm and flooding damages have increased by five and eleven times, respectively (Panwar et al., 2020).

Geographically, most seaports are located near the coast, serving as critical hubs for the transportation of goods. These seaports are highly vulnerable to rising sea levels, erosion, and other climate events, which can disrupt seaport operations and services. Therefore, having a mid- to long-term planning horizon is essential to ensure the continued operation and service of seaports (Hanson et al., 2020; Saadon et al., 2020; Becker et al., 2018; Becker et al., 2015; Liu et al., 2018). Rising sea levels can also raise concerns about maritime space and boundaries, particularly for coastal states, which can lead to political, economic, environmental, and security challenges (Agarwal et al., 2022). According to the United Nations Conference on Trade and Development (UNCTAD) survey, extreme events have led to delays, operational disruptions, and infrastructure damage (Sirimanne et al., 2017).

Seaports have experienced significant development to meet the increasing demand for trade (Becker et al., 2013). However, the extension and development of new seaport areas, which can alter coastlines, may lead to issues such as erosion and other negative impacts on ecosystems (Poo et al., 2022). Human-induced activities are exerting pressure on coastal areas, making them more vulnerable to extreme weather events (Molina et al., 2019). The IPCC Representative Concentration Pathway (RCP) scenarios indicate that under RCP 2.6 and RCP 8.5, seaport infrastructure damage could result in higher gross domestic product losses (Vrontisi et al., 2022). Moreover, the return period of extreme events has shortened, intensifying the impact of storm surges, severe flooding, and more frequent extreme sea level events (Cai et al., 2021). Under RCP 8.5 and by the year 2100, most docks may be severely affected. This could potentially lead to traffic losses of approximately 1.9 million TEUs and 22 million tonnes of cargo (Jebbad et al., 2022). Furthermore, landlocked countries often rely on nearby countries' seaports for their supply, which can be severely affected by extreme events (Hillebrandt-Andrade et al., 2021). Additionally, increasing emissions at seaports indirectly impact human health, causing severe illnesses due to air pollution (Gössling et al., 2021). Seaports are under tremendous pressure from authorities to comply with regulations and policies to control emissions. Several mitigation and adaptation approaches, such as onshore power supply, low-carbon seaport infrastructure, and fleet modernisation, will require significant investments, making prioritisation decisions challenging (Zhang et al., 2022). Furthermore, seaports are high energy users due to their operations and services. Implementing approaches and strategies involving alternative fuels will require substantial infrastructure investments, amounting to trillions of dollars (Krantz et al., 2020). Given the severity of CC, future adaptation and mitigation efforts will involve much higher costs and investments (Vrontisi et al., 2022).

Seaport disruptions can trigger a chain reaction, affecting various stakeholders and even entire countries through the global value chain (Zhang et al., 2017; Becker et al., 2015; Messner et al., 2015; Ryan-Henry et al., 2020). Understanding how harm spreads through stakeholders due to CC is essential for achieving comprehensive resilience planning (Moser et al., 2010; Becker et al., 2015). Additionally, rising sea levels can have positive impacts, such as reducing the need for seaport channel dredging, resulting in lower traffic congestion, and reducing operational maintenance work (Nugroho et al., 2016). It can also open new sea routes (NSR) that offer shorter distances and cost-effective transportation. These routes can reduce freight time by up to 20 days for cargo travelling from Asia to Europe and cut fuel costs by about 40% compared to the southern route (Biedermann, 2020). However, the negative aspect of this route is that it may lead to fewer port calls at seaports located in the southern region. CC has more negative impacts compared to positive ones. It results in severe service disruptions, economic and infrastructural losses, port congestion, supply disruptions, changes in economic patterns, more frequent extreme events, higher costs for recovery and maintenance, hinterland damages, and communication and network damages (Thakur, 2021).

The urgency of acknowledging and addressing the complex ramifications of CC on seaports, considering their pivotal role in global trade. The escalating occurrences of extreme weather events, amplified by rising global temperatures, significantly jeopardise the functionality of seaports, especially those situated along vulnerable coastal regions. The vulnerability of these seaports to rising sea levels, erosion, and disruptive climate events necessitates comprehensive mid to long-term planning strategies to ensure sustained operations.

Table 5.0: Impacts of Climate Change on Seaport

MAIN THEMES	SUB-THEMES	REFERENCE
Extreme Weather	Increasing trend in frequency of occurrence and intensity of extreme weather events such as flooding, strong winds, storm surges, tidal inundation, and drought with slower translation speed	Pavlović et al., 2020; Cai et al., 2021; Poo et al., 2022; Knutson et al., 2020; Hillebrandt-Andrade et al., 2021; Kossin et al., 2020
	Shortened return period of extreme events and intensified impacts	
Ice Sheet and Sea Levels	Melting of ice sheets and thermal expansion raising sea levels	Georgakakos et al., 2014
Coastal Dynamics	Increased damage due to extreme heat, storms, and flooding	Panwar et al., 2020; Molina et al., 2019; Hanson et al., 2020; Saadon et al., 2020; Becker et al., 2018; Becker et al., 2015; Liu et al., 2018
	Altered coastlines and negative impacts on ecosystems due to seaport development	
	Vulnerability of seaports to rising sea levels and coastal erosion	
Maritime Space and Boundaries	Concerns and dispute about maritime space and boundaries due to erosion and rising sea levels	Agarwal et al., 2022
Delays, Disruptions, and Infrastructure Damage	Delays, operational disruptions, and infrastructure damage due to extreme events and potential GDP losses	UNCTAD, 2017; Vrontisi et al., 2022; Jebbad et al., 2022; Zhang et al., 2017; Becker et al., 2015; Messner et al., 2015; Ryan-Henry et al., 2020
	Seaport disruptions affecting global value chains and stakeholders	
	Potential traffic losses and cargo disruption due to extreme events	
Landlocked Countries	Economics impact on landlocked countries relying on nearby seaports	Hillebrandt-Andrade et al., 2021
Human Health	Indirect impact on human health due to seaport emissions	Gössling et al., 2021
Mitigation &Adaptation	Need for compliance with emissions regulations and investments in mitigation and adaptation	Zhang et al., 2022
Energy Demand & Alternatives	High energy usage and the need for alternative fuels and infrastructure investments	Krantz et al., 2020
New Trading Routes	Emergence of new sea routes (Northern Sea Route)	Nugroho et al., 2016; Biedermann, 2020

4.9 Strategies by seaports to overcome climate change

Seaports and CC are closely interrelated, with both having a significant impact on the global economy and the environment. Understanding the current trends in CC and the factors related to seaports that can exacerbate CC events is essential. One of the key strategies for mitigating the impact of CC is to maintain global temperatures below a 2°C increase by reducing greenhouse gas emissions and achieving zero carbon emissions by 2050 (Gao et al., 2017). This effort can be achieved by developing a resilience plan that incorporates both adaptation and mitigation measures, and by guiding seaport operations, all of which can minimise their environmental impact. These plans should focus on seaport recovery capacity and their ability to withstand extreme weather events, considering physical, social, and economic factors. Establishing an index to measure seaport risk is vital in this regard (Laxe et al., 2012; Proag, 2014; Reggiani et al., 2015; Wang et al., 2020a; Phadikar, 2021).

Collaboration among internal stakeholders, tenants, clients, and public stakeholders to adhere to rules and regulations can reduce the cost of recovery and the intangible impacts of CC (Ryan-Henry & Becker, 2020). Furthermore, adaptation measures such as land-use planning, infrastructure investments, and the deployment of grey structures such as breakwaters, groynes, seawalls, landward evacuation, and relocation, as well as raising public awareness, are fundamental in addressing CC impacts, such as sea-level rise and extreme events (Cai et al., 2021). Prioritising infrastructure and technology investments can have a positive impact, increase the competitiveness of seaports, and stimulate demand for goods and services, ultimately leading to better economic growth (Vrontisi et al., 2022; Trzaska et al., 2014; Wu et al., 2020).

Seaport authorities and governments should prioritise investments in strategies to address climate uncertainty (Bauer et al., 2015). Various options and policies, such as dynamic strategic planning, multi-criteria analysis, adaptive seaport planning, assumption-based planning, what-if analysis and scenario analysis, can be employed to tackle climate uncertainty in the short and long term (De Neufville, 2000; Köksalan et al., 2011; Woo et al., 2018). In addition, advanced technologies in predicting and forecasting, such as probabilistic modelling, play a crucial role in assessing the magnitude of CC impacts (Kenéz & Joó, 2020). These tools are valuable for managing and planning seaport development by providing data for climate resilience and adaptation plans to minimise disruptions to seaport operations and reduce economic losses (Thakur, 2021).

Seaports are substantial energy users, contributing to higher greenhouse gas emissions due to energy production. Utilising renewable energy sources, such as marine, solar, and wind power as part of a green technology infrastructure can improve energy efficiency and reduce emissions (IPCC, 2011; Nguyen et al., 2022; Le et al., 2021; Nižetić et al., 2021; Chen et al., 2022; Nguyen et al., 2020; Hoang et al., 2021). Additionally, marine renewable energy sources, including offshore wind energy, ocean renewable energy, geothermal energy from submarine geothermal resources, and bioenergy from marine biomass, can be part of the solution to reduce emissions (Soria-Rodrigues, 2016). To increase carbon sequestration, seaports can implement an ecosystem approach by creating green buffer areas for tree planting (Agbelade and Onyekwelu, 2020). To encourage these environmentally friendly approaches, policies, economic incentives, and the application of port tariffs can be introduced (Mallouppas et al., 2021; Camargo-Diaz et al., 2022; Bergqvist et al., 2019; Mjelde et al., 2019). These policies, acting as discounts, can promote environmentally friendly practises (Christodolou et al., 2019; Tseng et al., 2019).

Furthermore, seaports have been associated with pollution and emissions, contributing to CC impacts. Prioritising emission reduction strategies in line with the decarbonisation strategies proposed by the International Maritime Organisation is crucial (Aregall et al., 2018). Achieving sustainable development goals and ensuring seaports stay green and smart is an ideal option (Nguyen et al., 2022; Darbra et al., 2005; Zhen et al., 2019). Green and smart ports can leverage technologies such as the Internet of Things (IoT), alternative energy sources, and advanced waste management practises (Vo et al., 2021; Lacki, 2021; Radwan et al., 2019).

Additionally, emissions at seaports during the loading and unloading process are a significant concern, exacerbated by an increase in ship calls (Cruz-Pérez et al., 2022). To reduce emissions, several strategies, such as onshore power supply, slowing ship speed, using alternative fuels, optimising berth scheduling, routing control to manage carbon dioxide emissions, and reducing idling time, can be implemented (Bergqvist et al., 2019; Radwan et al., 2019; Anser et al., 2020; Gallo et al., 2020; Poo et al., 2022). Furthermore, reducing ship emissions through the use of alternative fuels and international cooperation in developing technologies should be prioritised to combat these emissions (Zhmur et al., 2017; Yeremenko, 2022; Hoang et al., 2021; Murugesan et al., 2021; Hadiyanto et al., 2022; Truoang et al., 2021).

The intricate relationship between seaports and CC underscores the urgent need for comprehensive strategies that address their interdependencies and impact on the global economy and environment. Mitigating CC necessitates stringent measures to limit global temperature increases, aiming for zero carbon emissions by 2050. This demands resilience plans for seaports, blending adaptation and mitigation strategies to withstand extreme events and minimise environmental impact while ensuring uninterrupted operations. Effective collaboration among stakeholders and adherence to regulations can mitigate intangible CC impacts and reduce recovery costs. Prioritising adaptation measures such as infrastructure investments, land-use planning, and deploying resilient structures is vital to countering rising sea levels and extreme events, thereby fostering economic growth and competitiveness.

Table 6.0: Strategy to Overcome Climate Change impact

MAIN THEMES	SUB-THEMES	REFERENCE
Keeping Temperatures Down	Maintaining global temperatures below 2°C	Gao et al., 2017
Seaport Resilience	Developing resilience plans for seaports	Laxe et al., 2012; Proag, 2014; Reggiani et al., 2015; Wang et al., 2020a; Phadikar, 2021
Working Together	Collaboration among stakeholders to reduce recovery costs	Ryan-Henry & Becker, 2020
Adaptation and Investment	Adaptation measures and infrastructure investments	Cai et al., 2021; Vrontisi et al., 2022; Trzaska et al., 2014; Wu et al., 2020; Bauer et al., 2015; De Neufville, 2000; Köksalan et al., 2011; Woo et al., 2018; Kenéz & Joó, 2020; Gonzales Aregall et al., 2018; Cruz-Pérez et al., 2022; Bergqvist et al., 2019; Radwan et al., 2019; Anser et al., 2020; Gallo et al., 2020; Poo et al., 2022
	Prioritising infrastructure and technology investments	
	Strategies to address climate uncertainty	
	Advanced technologies for predicting and forecasting climate impacts	
	Prioritising emission reduction strategies in seaports	
Renewable Energy for Seaports	Utilising renewable energy sources for seaport operations	IPCC, 2011; Nguyen et al., 2022; Le et al., 2021; Nižetić et al., 2021; Wang et al., 2020a; Nguyen et al., 2020; Hoang et al., 2021
Carbon Sequestration	Implementing ecosystem approaches for carbon sequestration	Agbelade and Onyekwelu, 2020
Eco-friendly Policies	Introducing policies, incentives, and port tariffs for eco-friendly practices	Mallouppas et al., 2021; Camargo-Diaz et al., 2022; Bergqvist et al., 2019; Mjelde et al., 2019
Sustainable Port Practices	Achieving sustainable development goals and green/smart port practices	Nguyen et al., 2022; Darbra et al., 2005; Zhen et al., 2019
Alternative Fuels and International Cooperation	Reducing ship emissions through alternative fuels and international cooperation	Zhmur et al., 2017; Yeremenko, 2022; Hoang et al., 2021; Murugesan et al., 2021; Hadiyanto et al., 2022; Truong et al., 2021

5.0 Discussion

The CC impact on coastal entities, such as seaports, is undeniable, and these impacts manifest in the form of storm surges, flooding, heatwaves, inundation, erosion, and more. These climate events are becoming increasingly extreme in terms of frequency and intensity, with the average recurrence interval of extreme events shortening. Additionally, climate variability, a naturally occurring process due to seasonal fluctuations, contributes to extended events such as droughts, heatwaves, and flooding. When CC and climate variability coincide, the resulting weather-related events become prolonged, extreme, and disastrous.

Additionally, the severity of these impacts triggers a chain reaction that affects the regional and global economies, leading to significant disruptions. The rise in global mean sea level is attributed to the melting of Arctic ice, a consequence of global warming. Furthermore, global temperatures, the ultimate key to CC, are observed to be rising compared to pre-industrial levels due to the increasing concentration of greenhouse gases (GHGs). These GHGs act as a blanket, trapping heat and causing an imbalance in Earth’s radiation, resulting in global warming and alterations to the climate system. Anthropogenic activities are primarily responsible for the perturbations leading to CC.

Seaports serve as critical nodes in global trade and coastal transportation that have undergone substantial development in recent years to meet demand while contributing to regional and global economies. However, CC adversely affects seaport operations and services, leading to delays, disruptions, and infrastructure damage. CC can have both direct and indirect impacts on seaports. Direct impacts include infrastructure damage, and operational disruptions, while indirect impacts encompass reduced port calls, investment choices, demographic shifts, and more. Notably, privately-owned seaports often prioritise investments to enhance profitability while neglecting the surrounding ecosystem and factors contributing to CC.

Moreover, seaports’ adaptation and mitigation efforts are often reactive, based on daily impacts or worst-case scenarios, leading to failures, such as the failure of grey structures such as breakwaters and seawalls during extreme weather events. This results in severe damage to cargo and infrastructure, imposing substantial recovery costs on seaports. Landlocked countries heavily depend on nearby seaports due to the cost-effectiveness of shipping, and any service disruption can lead to economic losses. Thus, it is crucial to develop climate resilience plans for seaports to address climate-related challenges effectively. Furthermore, seaports significantly contribute to CC, from construction to operation. During construction, nearby ecosystems are cleared, causing environmental damage, and altering coastal alignment leads to severe erosion, flooding, and inundation. During operation, seaports emit GHGs from stationary sources such as power plants, industrial facilities, and the electrical grid, as well as from mobile sources such as ships and machinery. Although shipping is considered a lower GHG emitter compared to other transportation modes, the recent growth in trading, driven by globalisation, requires exploring alternatives. Most tools used in seaport operations rely heavily on fossil fuels, making seaports high energy consumers, which, in turn, leads to increased emissions contributing to CC and causing health issues for nearby communities.

It is also important to initiate collaboration and cooperation among stakeholders, port tenants, government entities, universities, and other agencies to create a solid foundation. Research and development play a vital role in developing alternatives for more effective adaptation and mitigation solutions. The concept of green and smart ports offers multiple options, such as incentives for clients adhering to green policies, motivating them to find solutions to achieve objectives and receiving discounts. Marine renewable energy and microgrids hold promise for offering zero-emission solutions through kinetic energy generation. While choosing electrification or hybrid modes for seaport tools and machinery is a step in the right direction, certain seaports heavily dependent on coal-fired power plants must also be addressed to curb the detrimental impacts of the by-products on the environment and human health.

The combination of microgrids, adherence to green policies, and the transition to green seaports with marine renewable energy will govern seaport operations, aligning with sustainability principles. As part of the Sustainable Development Goals (SDGs), the top priority is to minimise the impact of CC by reducing emissions. Implementing environmental, social, and governance (ESG) practises provides organisational-level monitoring and accountability. Furthermore, while the framework offers various solutions to address environmental issues, its success is often hindered by a lack of understanding and competence in certain countries. It is essential to recognise that emissions from developing countries are higher due to economic differences compared to those from developed countries. Therefore, cooperation and collaboration among countries in sharing knowledge are fundamental to achieving SDG goals.

6.0 Conclusion and implication

A seaport is an important asset that needs to be preserved and protected from various negativities mainly weather-related events. Apart from being threatened by CC, factors stemming from seaport activities have significantly been impulsive contributors to CC. One of the factors is greenhouse gas (GHG) emissions from ships, which are considered a major contributor. Moreover, ships have been used as a major transport mode due to their cost effectiveness and as an ideal way of transporting large volumes of cargo. In context, during berthing operations (Loading/unloading) and also during voyages, ships emit a large amount of GHG that directly contributes to CC. In this context, growing economies and global trade in the near future may cause a high number of vessels while increasing GHG emission.

The continuity of the seaport in operating and providing services is crucial, as the seaport acts as an economic bridge for regional and global activities, which necessitates minimising negative environmental impacts. Recent events such as Suez Canal blockages, Hurricane Katrina, Hurricane Maria and Superstorm Sandy indicate that CC has been progressively causing weather related disruptions that resulted in seaport failures that caused major economic losses. Extreme weather events are noticed to increase in terms of frequency of occurrence and also in terms of intensity. An incident such as the blockage of the Suez Canal shows the capability of an extreme event to cause major upholds in global trade. Damages to seaport infrastructure and equipment in the near future due to extreme weather events could cost a fortune and subsequently, a catastrophic business failure.

Countermeasures such as adaptation and mitigation should be prioritised and be a part of the investment choice to help prepare the seaport in terms of extreme weather events and minimise the abovementioned contributing factors. In order to curb the contributing factors, stakeholders, the government sector, port tenants, and other parties should cooperate and collaborate in finding alternatives. Investment in alternate technologies has served the best in solving the seaport factor, but the cost involved further burdens the seaport authority. In addition, in the near future seaport recovery is forecast to increase due to damages left by CC. Furthermore, the detrimental effect on human health brings concern to communities nearby the seaport. The awareness programme also plays a big role, as this activity helps to preserve the environment and understand the impacts of CC better. In conclusion, this paper has highlighted the significant role of seaports in global trade and their vulnerability to CC-related disruptions, including sea-level rise, extreme weather events, and their impacts on economic operations. In essence, this research underscores the urgency of taking proactive measures to ensure the resilience and sustainability of seaports in the face of CC. Evidently, seaports can play a crucial role in mitigating their environmental impact and maintaining their vital role in global trade by prioritising green and smart port practises, investing in renewable energy sources, and fostering international cooperation.

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References

Agarwal, S.K. and Agnihotri, K.K., 2022. UNCLOS and climate-induced maritime challenges: Strategic implications for the Indian Ocean Region. Maritime Affairs: Journal of the National Maritime Foundation of India, Vol. 18 No. 1, pp. 55-71.

Agbelade, A.D. and Onyekwelu, J.C., 2020. Tree species diversity, volume yield, biomass and carbon sequestration in urban forests in two Nigerian cities. Urban Ecosystems, Vol. 23 No. 5, pp. 957-970.

Anser, M.K., Yousaf, Z., Usman, B., Nassani, A.A., Abro, M.M.Q. and Zaman, K., 2020. Management of water, energy, and food resources: go for green policies. Journal of Cleaner Production, Vol. 251, p. 119662.

Aregall, M.G., Bergqvist, R. and Monios, J., 2018. A global review of the hinterland dimension of green port strategies. Transportation Research Part D: Transport and Environment, Vol. 59, pp. 23-34.

Asoriotis, R., Benamara, H. and Mohos-Naray, V., 2017. Port industry survey on climate change impacts and adaptation. UN.

Bakır, H., Ağbulut, Ü., Gürel, A.E., Yıldız, G., Güvenç, U., Soudagar, M.E.M., Hoang, A.T., Deepanraj, B., Saini, G. and Afzal, A., 2022. Forecasting of future greenhouse gas emission trajectory for India using energy and economic indexes with various metaheuristic algorithms. Journal of Cleaner Production, Vol. 360, p. 131946.

Bauer, P., Thorpe, A. and Brunet, G., 2015. The quiet revolution of numerical weather prediction. Nature, Vol. 525 No. 7567, pp. 47-55.

Becker, A.H., Acciaro, M., Asariotis, R., Cabrera, E., Cretegny, L., Crist, P., Esteban, M., Mather, A., Messner, S., Naruse, S. and Ng, A.K., 2013. A note on climate change adaptation for seaports: a challenge for global ports, a challenge for global society. Climatic change, Vol. 120, pp. 683-695.

Becker, A.H., Matson, P., Fischer, M. and Mastrandrea, M.D., 2015. Towards seaport resilience for climate change adaptation: Stakeholder perceptions of hurricane impacts in Gulfport (MS) and Providence (RI). Progress in Planning, Vol. 99, pp. 1-49.

Becker, A., Inoue, S., Fischer, M. and Schwegler, B., 2012. Climate change impacts on international seaports: knowledge, perceptions, and planning efforts among port administrators. Climatic change, Vol. 110 No. 1, pp. 5-29.

Becker, A., Ng, A.K., McEvoy, D. and Mullett, J., 2018. Implications of climate change for shipping: Ports and supply chains. Wiley Interdisciplinary Reviews: Climate Change, Vol. 9 No. 2, p.e 508.

Bergqvist, R. and Monios, J., 2019. Green ports in theory and practice. In Green ports (pp. 1-17). Elsevier.

Biedermann, R., 2020. Adapting to the changing Arctic? The European Union, the Nordics, and the Barents Governance Mosaic. Journal of Contemporary European Studies, Vol. 28 No. 2, pp. 167-181.

Bolbot, V., Kulkarni, K., Brunou, P., Banda, O.V. and Musharraf, M., 2022. Developments and research directions in maritime cybersecurity: A systematic literature review and bibliometric analysis. International Journal of Critical Infrastructure Protection, Vol. 39, p. 100571.

Brigham, L.W. and Gamble, J.T., 2022. Strategy for protecting the future Arctic Ocean. Oceanography, Vol. 35 No. 3/4, pp. 167-177.

Brouer, B.D., Karsten, C.V. and Pisinger, D., 2017. Optimization in liner shipping. 4OR, Vol. 15, pp. 1-35.

Buhaug, Ø., Corbett Endresen, Ø., Eyring, V., Faber, J., Hanayama, S., Lee, D.S., Lee, D., Lindstad, H., Markowska, A.Z. and Mjelde, A., 2009. Second IMO GHG study 2009.

Butt, N., 2007. The impact of cruise ship generated waste on home ports and ports of call: A study of Southampton. Marine Policy, Vol. 31 No. 5, pp. 591-598.

Cai, O., Peng, C. and Yu, X., 2021, February. The development of port emissions inventory from decision-making perspective: case of the port of Los Angeles. In IOP Conference Series: Earth and Environmental Science Vol. 675 No. 1 p. 012022. IOP Publishing.

Camargo-Díaz, C.P., Paipa-Sanabria, E., Zapata-Cortes, J.A., Aguirre-Restrepo, Y. and Quiñones-Bolaños, E.E., 2022. A Review of Economic Incentives to Promote Decarbonization Alternatives in Maritime and Inland Waterway Transport Modes. Sustainability, Vol. 14 No. 21, p. 14405.

Cao, Y., Wang, X., Yang, Z., Wang, J., Wang, H. and Liu, Z., 2023. Research in marine accidents: A bibliometric analysis, systematic review and future directions. Ocean Engineering, Vol. 284, p. 115048.

Chapapría, V.E. and Peris, J.S., 2021. Vulnerability of coastal areas due to infrastructure: The case of Valencia port (Spain). Land, Vol. 10 No. 12, p. 1344.

Chen, J., Zheng, T., Garg, A., Xu, L., Li, S. and Fei, Y., 2019. Alternative maritime power application as a green port strategy: Barriers in China. Journal of Cleaner Production, Vol. 213, pp. 825-837.

Chen, W.H., Hoang, A.T., Nižetić, S., Pandey, A., Cheng, C.K., Luque, R., Ong, H.C., Thomas, S. and Nguyen, X.P., 2022. Biomass-derived biochar: From production to application in removing heavy metal-contaminated water. Process Safety and Environmental Protection, Vol. 160, pp.704-733.

Chen, W.H., Wang, J.S., Chang, M.H., Hoang, A.T., Lam, S.S., Kwon, E.E. and Ashokkumar, V., 2022. Optimization of a vertical axis wind turbine with a deflector under unsteady wind conditions via Taguchi and neural network applications. Energy Conversion and Management, Vol. 254, p. 115209.

Christodoulou, A., Gonzalez-Aregall, M., Linde, T., Vierth, I. and Cullinane, K., 2019. Targeting the reduction of shipping emissions to air: A global review and taxonomy of policies, incentives and measures. Maritime Business Review, Vol. 4 No. 1, pp. 16-30.

Comer, B., Osipova, L., Georgeff, E. and Mao, X., 2020. The international maritime organization's proposed arctic heavy fuel oil ban: Likely impacts and opportunities for improvement. The International Council on Clean Transportation, Washington, DC.

Cruz-Pérez, N., Dessimoz, M.D., Rodríguez-Martín, J., García, C., Ioras, F. and Santamarta, J.C., 2022. Carbon and water footprints of marinas in the Canary Islands (Spain). Coastal Management, Vol. 50 No. 5, pp. 408-418.

Cullinane, K. and Cullinane, S., 2019. Policy on reducing shipping emissions: implications for "green ports". Green Ports, pp.35-62.

da Silva, F.F., Filser, L.D., Juliani, F. and de Oliveira, O.J., 2018. Where to direct research in lean six sigma? Bibliometric analysis, scientific gaps and trends on literature. International Journal of Lean Six Sigma, Vol. 9 No. 3, pp. 324-350.

Darbra, R.M., Ronza, A., Stojanovic, T.A., Wooldridge, C. and Casal, J., 2005. A procedure for identifying significant environmental aspects in sea ports. Marine pollution bulletin, Vol. 50 No.8, pp. 866-874.

De Oliveira, R.I., Sousa, S.O. and De Campos, F.C., 2019. Lean manufacturing implementation: bibliometric analysis 2007–2018. The International Journal of Advanced Manufacturing Technology, Vol. 101, pp. 979-988.

Devendran, L., Menhat, M., Md Hanafiah, R., Yatim, N.I., Ali, N.A. and Mohd Zaideen, I.M., 2023. Adapting to the impacts of climate change on port operation. Australian Journal of Maritime & Ocean Affairs, Vol. 15 No. 2, pp. 107-126.

DNV, 2021. Ocean's future to 2050: a sectoral and regional forecast of the blue economy.

Dobson, N.L., 2020. Competing climate change responses: Reflections on EU unilateral regulation of international transport emissions in light of multilateral developments. Netherlands International Law Review, Vol. 67 No. 2, pp.183-210.

Drosińska-Komor, M., Głuch, J., Breńkacz, Ł. and Ziółkowski, P., 2022. On the use of selected 4th generation nuclear reactors in marine power plants. Polish Maritime Research, Vol. 29 No. 1, pp. 76-84.

European State of The Climate (ESOTC). (2022). European State of the Climate Summary 2022.https://climate.copernicus.eu/sites/default/files/customuploads/ESOTC2022/PR/ESOTCsummary2022_final.pdf.

Ezinna, P.C., Nwanmuoh, E. and Ozumba, B.U.I., 2021. Decarbonization and sustainable development goal 13: A reflection of the maritime sector. Journal of International Maritime Safety, Environmental Affairs, and Shipping, Vol. 5 No. 2, pp. 98-105.

Faber, J., Hanayama, S., Zhang, S., Pereda, P., Comer, B., Hauerhof, E., … Yuan, H. (2020). Fourth IMO greenhouse gas study. International Maritime Organization. https://www.imo.org/en/OurWork/Environment/Pages/Fourth-IMO-Greenhouse-Gas-Study-2020.aspx

Fu, S., Goerlandt, F. and Xi, Y., 2021. Arctic shipping risk management: A bibliometric analysis and a systematic review of risk influencing factors of navigational accidents. Safety science, Vol. 139, p. 105254.

Gallo, M., Moreschi, L., Mazzoccoli, M., Marotta, V. and Del Borghi, A., 2020. Sustainability in maritime sector: Waste management alternatives evaluated in a circular carbon economy perspective. Resources, Vol. 9 No. 4, p. 41.

Gao, Y., Gao, X. and Zhang, X., 2017. The 2 C global temperature target and the evolution of the long-term goal of addressing climate change—from the United Nations framework convention on climate change to the Paris agreement. Engineering, Vol. 3 No. 2, pp. 272-278.

Georgakakos, A., Fleming, P., Dettinger, M., Peters-Lidard, C., Richmond, T., Reckhow, K., White, K. and Yates, D., 2014. Climate Change Impacts in the United States: The Third National Climate Assessment. Melillo, JM, Richmond, TC, Yohe, GW, Eds, pp. 69-112.

Gibbs, D., Rigot-Muller, P., Mangan, J. and Lalwani, C., 2014. The role of sea ports in end-to-end maritime transport chain emissions. Energy Policy, Vol. 64, pp. 337-348.

Gil, M., Wróbel, K., Montewka, J. and Goerlandt, F., 2020. A bibliometric analysis and systematic review of shipboard Decision Support Systems for accident prevention. Safety science, Vol. 128, p. 104717.

Gössling, S., Meyer-Habighorst, C. and Humpe, A., 2021. A global review of marine air pollution policies, their scope and effectiveness. Ocean & Coastal Management, Vol. 212, p. 105824.

Hadiyanto, H., Christwardana, M., Pratiwi, W.Z., Purwanto, P., Sudarno, S., Haryani, K. and Hoang, A.T., 2022. Response surface optimization of microalgae microbial fuel cell (MMFC) enhanced by yeast immobilization for bioelectricity production. Chemosphere, Vol. 287, p. 132275.

Hall, W.J., 2010. Assessment of CO2 and priority pollutant reduction by installation of shoreside power. Resources, Conservation and Recycling, Vol. 54 No. 7, pp. 462-467.

Hanson, S.E. and Nicholls, R.J., 2020. Demand for ports to 2050: Climate policy, growing trade and the impacts of sea-level rise. Earth's Future, Vol. 8 No. 8, p.e2020EF001543.

Hillebrandt-Andrade, C.V., Blythe-Mallett, A. and Escobar-Briones, E., 2021. Co-Designing a safe ocean in the Western Tropical Atlantic within the framework of the UN Decade of Ocean Science for Sustainable Development. Ocean and Coastal Research, Vol. 69, p.e 21035.

Hoang, A.T. and Nguyen, X.P., 2021. Integrating renewable sources into energy system for smart city as a sagacious strategy towards clean and sustainable process. Journal of Cleaner Production, Vol. 305, p. 127161.

Hoang, A.T., Nižetić, S., Cheng, C.K., Luque, R., Thomas, S., Banh, T.L. and Nguyen, X.P., 2022. Heavy metal removal by biomass-derived carbon nanotubes as a greener environmental remediation: A comprehensive review. Chemosphere, Vol. 287, p. 131959.

IPCC, 2011. IPCC special report on renewable energy sources and climate change mitigation.

Jebbad, R., Sierra, J.P., Mösso, C., Mestres, M. and Sánchez-Arcilla, A., 2022. Assessment of harbour inoperability and adaptation cost due to sea level rise. Application to the port of Tangier-Med (Morocco). Applied Geography, Vol. 138, p. 102623.

Jiang, C., Zheng, S., Ng, A.K., Ge, Y.E. and Fu, X., 2020. The climate change strategies of seaports: Mitigation vs. adaptation. Transportation Research Part D: Transport and Environment, Vol. 89, p. 102603.

Jouili, T., 2016. The role of seaports in the process of economic growth. Developing country studies, Vol. 6 No. 2, pp. 64-69.

Kanchiralla, F.M., Brynolf, S., Malmgren, E., Hansson, J. and Grahn, M., 2022. Life-cycle assessment and costing of fuels and propulsion systems in future fossil-free shipping. Environmental science & technology, Vol. 56 No. 17, pp. 12517-12531.

Kenéz, Á. and Joó, A.L., 2020. Parameter estimation and threshold selection uncertainty in extreme wind speed distribution–A frequentist approach with generalized Pareto distribution using automatic threshold selection. Időjárás/Quarterly Journal of the Hungarian Meteorological Service, Vol. 124 No. 3, pp. 311-330.

Knutson, T., Camargo, S.J., Chan, J.C., Emanuel, K., Ho, C.H., Kossin, J., Mohapatra, M., Satoh, M., Sugi, M., Walsh, K. and Wu, L., 2020. Tropical cyclones and climate change assessment. Bulletin of the American Meteorological Society, Vol. 101 No. 3, pp. E303-E322.

Köksalan, M.M., Wallenius, J. and Zionts, S., 2011. Multiple criteria decisions making: from early history to the 21st century. World Scientific.

Kossin, J.P., Knapp, K.R., Olander, T.L. and Velden, C.S., 2020. Global increase in major tropical cyclone exceedance probability over the past four decades. Proceedings of the National Academy of Sciences, Vol. 117 No. 22, pp. 11975-11980.

Kouakou, M., Bonou, F., Gnandi, K., Djagoua, E., Idrissou, M. and Abunkudugu, A., 2023. Determination of current and future extreme sea levels at the local scale in port-Bouët Bay (Côte d'Ivoire). Journal of Marine Science and Engineering, Vol. 11 No. 4, p. 756.

Krantz, R., Søgaard, K. and Smith, T., 2020. The scale of investment needed to decarbonize international shipping. Getting to zero coalition insight series,(January), pp.3-6.

Łącki, M., 2021. An adaptive island model of population for neuroevolutionary ship handling. Polish Maritime Research, Vol. 28 No. 4, pp. 142-150.

Laxe, F.G., Seoane, M.J.F. and Montes, C.P., 2012. Maritime degree, centrality and vulnerability: port hierarchies and emerging areas in containerized transport (2008–2010). Journal of Transport Geography, Vol. 24, pp. 33-44.

Le, T.H., Pham, M.T., Hadiyanto, H. and Hoang, A.T., 2021. Influence of various basin types on performance of passive solar still: a review. International Journal of Renewable Energy Development, Vol. 10 No. 4, pp. 789-802.

León-Mateos, F., Sartal, A., López-Manuel, L. and Quintas, M.A., 2021. Adapting our sea ports to the challenges of climate change: Development and validation of a Port Resilience Index. Marine Policy, Vol. 130, p. 104573.

Lin, C., Cohen, J.B., Wang, S., Lan, R. and Deng, W., 2020. A new perspective on the spatial, temporal, and vertical distribution of biomass burning: quantifying a significant increase in CO emissions. Environmental Research Letters, Vol. 15 No. 10, p. 104091.

Liu, H., Tian, Z., Huang, A. and Yang, Z., 2018. Analysis of vulnerabilities in maritime supply chains. Reliability Engineering & System Safety, Vol. 169, pp. 475-484.

Mallouppas, G. and Yfantis, E.A., 2021. Decarbonization in shipping industry: A review of research, technology development, and innovation proposals. Journal of Marine Science and Engineering, Vol. 9 No. 4, p. 415.

Masson-Delmotte, V.P., Zhai, P., Pirani, S.L., Connors, C., Péan, S., Berger, N., Caud, Y., Chen, L., Goldfarb, M.I. and Scheel Monteiro, P.M., 2021a. IPCC, 2021: Summary for policymakers. in: Climate change 2021: The physical science basis. contribution of working group i to the sixth assessment report of the intergovernmental panel on climate change.

Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S.L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M.I. and Huang, M., 2021b. Climate change 2021: The physical science basis. Contribution of working group I to the sixth assessment report of the intergovernmental panel on climate change, Vol. 2 No. 1, p. 2391.

Meng, J., Mi, Z., Guan, D., Li, J., Tao, S., Li, Y., Feng, K., Liu, J., Liu, Z., Wang, X. and Zhang, Q., 2018. The rise of South–South trade and its effect on global CO2 emissions. Nature communications, Vol. 9 No. 1, p. 1871.

Messner, S., Becker, A. and Ng, A.K., 2015. Port adaptation for climate change: The roles of stakeholders and the planning process. In Climate change and adaptation planning for ports (pp. 41-55). Routledge.

Meyers, S.D., Azevedo, L. and Luther, M.E., 2021. A Scopus-based bibliometric study of maritime research involving the Automatic Identification System. Transportation research interdisciplinary perspectives, Vol. 10, p. 100387.

Mjelde, A., Endresen, Ø., Bjørshol, E., Gierløff, C.W., Husby, E., Solheim, J., Mjøs, N. and Eide, M.S., 2019. Differentiating on port fees to accelerate the green maritime transition. Marine pollution bulletin, Vol. 149, p. 110561.

Molina, R., Anfuso, G., Manno, G. and Gracia Prieto, F.J., 2019. The Mediterranean coast of Andalusia (Spain): Medium-term evolution and impacts of coastal structures. Sustainability, Vol. 11 No. 13, p. 3539.

Morris, R.L., Boxshall, A. and Swearer, S.E., 2020. Climate-resilient coasts require diverse defence solutions. Nature Climate Change, Vol. 10 No. 6, pp. 485-487.

Moser, S.C. and Ekstrom, J.A., 2010. A framework to diagnose barriers to climate change adaptation. Proceedings of the national academy of sciences, Vol. 107 No. 51, pp. 22026-22031.

Munim, Z.H., Dushenko, M., Jimenez, V.J., Shakil, M.H. and Imset, M., 2020. Big data and artificial intelligence in the maritime industry: a bibliometric review and future research directions. Maritime Policy & Management, Vol. 47 No. 5, pp. 577-597.

Murugesan, P., Hoang, A.T., Venkatesan, E.P., Kumar, D.S., Balasubramanian, D. and Le, A.T., 2022. Role of hydrogen in improving performance and emission characteristics of homogeneous charge compression ignition engine fueled with graphite oxide nanoparticle-added microalgae biodiesel/diesel blends. International Journal of Hydrogen Energy, Vol. 47 No. 88, pp. 37617-37634.

Neufville, R.D., 2000. Dynamic strategic planning for technology policy. International Journal of Technology Management, Vol. 19 No. 3-5, pp. 225-245.

Nguyen, H.P., Nguyen, P.Q.P. and Nguyen, T.P., 2022. Green Port Strategies in Developed Coastal Countries as Useful Lessons for the Path of Sustainable Development: A case study in Vietnam. International Journal of Renewable Energy Development, Vol. 11 No. 4, pp. 950-962.

Nguyen, X.P. and Hoang, A.T., 2020, March. The flywheel energy storage system: An effective solution to accumulate renewable energy. In 2020 6th International Conference on Advanced Computing and Communication Systems (ICACCS) (pp. 1322-1328). IEEE.

Nižetić, S., Jurčević, M., Čoko, D., Arıcı, M. and Hoang, A.T., 2021. Implementation of phase change materials for thermal regulation of photovoltaic thermal systems: Comprehensive analysis of design approaches. Energy, Vol. 228, p. 120546.

Nugroho, E.S., 2016. Development of Climate Resilient Ports: Achieving Viable and Efficient Investments in Landlord Container Terminals.

Olmer, N., Comer, B., Roy, B., Mao, X. and Rutherford, D., 2017. Greenhouse gas emissions from global shipping, 2013–2015 Detailed Methodology. International Council on Clean Transportation: Washington, DC, USA, pp.1-38.

Panwar, V. and Sen, S., 2020. Disaster damage records of EM-DAT and DesInventar: a systematic comparison. Economics of disasters and climate change, Vol. 4 No. 2, pp. 295-317.

Papić, D., Bačević, N.R., Valjarević, A., Milentijević, N., Gavrilov, M.B., Živković, M. and Marković, S.B., 2020. Assessment of air temperature trend in South and Southeast Bosnia and Herzegovina from 1961 to 2017. IDŐJÁRÁS/QUARTERLY JOURNAL OF THE HUNGARIAN METEOROLOGICAL SERVICE, Vol. 124 No. 3, pp. 381-399.

Pavlović, M., Krstić, F., Živanović, V. and Kovjanić, A., 2020. Valorisation of climate conditions in tourist centers of South Serbia. IDŐJÁRÁS/QUARTERLY JOURNAL OF THE HUNGARIAN METEOROLOGICAL SERVICE, Vol. 124 No. 3, pp. 363-380.

Pham, V.V., Hoang, A.T. and Do, H.C., 2020, May. Analysis and evaluation of database for the selection of propulsion systems for tankers. In AIP Conference Proceedings, Vol. 2235 No. 1. AIP Publishing.

Poo, M.C.P. and Yang, Z., 2022. Optimising the resilience of shipping networks to climate vulnerability. Maritime Policy & Management, Vol. 51 No. 1, pp. 15-34.

Poo, M.C.P., Yang, Z., Dimitriu, D., Qu, Z., Jin, Z. and Feng, X., 2021. Climate change risk indicators (CCRI) for seaports in the United Kingdom. Ocean & Coastal Management, Vol. 205, p. 105580.

Proag, V., 2014. The concept of vulnerability and resilience. Procedia Economics and Finance, Vol. 18, pp. 369-376.

Pruyn, J.F.J. and Van Hassel, E.B.H.J., 2022. The impact of adding the Northern Sea route to the Belt and Road Initiative for Europe: A chain cost approach. Transportation Research Interdisciplinary Perspectives, Vol. 15, p. 100659.

Radwan, M.E., Chen, J., Wan, Z., Zheng, T., Hua, C. and Huang, X., 2019. Critical barriers to the introduction of shore power supply for green port development: case of Djibouti container terminals. Clean Technologies and Environmental Policy, Vol. 21, pp. 1293-1306.

Reggiani, A., Nijkamp, P. and Lanzi, D., 2015. Transport resilience and vulnerability: The role of connectivity. Transportation research part A: policy and practice, Vol. 81, pp. 4-15.

Romppanen, S., 2018. Arctic climate governance via EU law on black carbon?. Review of European, Comparative & International Environmental Law, Vol. 27 No. 1, pp. 45-54.

Ryan-Henry, J. and Becker, A., 2020. Port stakeholder perceptions of Sandy impacts: A case study of Red Hook, New York. Maritime Policy & Management, Vol. 47 No. 7, pp. 885-902.

Saadon, M.S.I., Ab Wahida, N.S., Othman, M.R., Nor, D.A.M., Mokhtar, F.S., Nordin, N., Kowang, T.O. and Nordin, L., 2020. An evaluation of the impact of coastal erosion to the environment and economic activities at Mengabang Telipot, Terengganu. J. Crit. Rev, 7, pp. 1132-1136.

Savu, S.V., Marin, R.C., David, A., Olei, A.B., Dumitru, I., Tarnita, D., Maternova, A. and Savu, I.D., 2022. Reducing NOx emissions through microwave heating of aftertreatment systems for sustainable transport in the inland waterway sector. Sustainability, Vol. 14 No. 7, p. 4156.

Schlanger, Z., 2018. If shipping were a country, it would be the world’s sixth-biggest greenhouse gas emitter. In World Economic Forum. https://www. weforum. org/agenda/2018/04/if-shipping-were-a-country-it-would-be-the-world-s-sixth-biggest-greenhouse-gas-emitter.

Selvaduray, M., Bandara, Y.M., Zain, R.M., Ramli, A. and Mohd Zain, M.Z., 2023. Bibliometric analysis of maritime tourism research. Australian Journal of Maritime & Ocean Affairs, Vol. 15 No. 3, pp. 330-356.

Sirimanne, S.N., Hoffman, J., Juan, W., Asariotis, R., Assaf, M., Benamar, H., Fugazza, M., Hoffmann, J., Premti, A., Rodríguez, L., Ugaz, P., Weller, M. and Youssef, Frida., 2017. Review of maritime transport 2017.

Song, D., 2021. A literature review, container shipping supply chain: Planning problems and research opportunities. Logistics, Vol. 5 No. 2, p. 41.

Soria-Rodríguez, C., 2016. Marine renewable energies and the European regional seas conventions. Climate Law, Vol. 6 No. 3-4, pp. 314-335.

Strawa, A.W., Latshaw, G., Farkas, S., Russell, P. and Zornetzer, S., 2020. Arctic ice loss threatens national security: A path forward. Orbis, Vol. 64 No. 4, pp. 622-636.

Styhre, L., Bahr, J.V., Bäckström, S., Hult, C., Jivén, K., Parsmo, R., Romson, Å., Sköld, S. and Winnes, H., 2019. Environmental differentiated port dues.

Thakur, S., 2021. Ports and climate uncertainty: An economic imperative for India. Maritime Affairs: Journal of the National Maritime Foundation of India, Vol. 17 No. 2, pp. 91-106.

Truong, T.T., Nguyen, X.P., Pham, V.V., Le, V.V., Le, A.T. and Bui, V.T., 2021. Effect of alcohol additives on diesel engine performance: a review. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, pp.1-25.

Trzaska, S. and Schnarr, E., 2014. A review of downscaling methods for climate change projections. United States Agency for International Development by Tetra Tech ARD, Vol. 45 No. 05, pp. 45-2621.

Tseng, P.H. and Pilcher, N., 2019. Evaluating the key factors of green port policies in Taiwan through quantitative and qualitative approaches. Transport Policy, Vol. 82, pp. 127-137.

Van der Wiel, K. and Bintanja, R., 2021. Contribution of climatic changes in mean and variability to monthly temperature and precipitation extremes. Communications Earth & Environment, Vol. 2 No. 1, p.1.

Vitousek, S., Barnard, P.L., Fletcher, C.H., Frazer, N., Erikson, L. and Storlazzi, C.D., 2017. Doubling of coastal flooding frequency within decades due to sea-level rise. Scientific reports, Vol. 7 No. 1, p. 1399.

Vo, D.T., Nguyen, X.P., Nguyen, T.D., Hidayat, R., Huynh, T.T. and Nguyen, D.T., 2021. A review on the internet of thing (IoT) technologies in controlling ocean environment. Energy sources, Part A: Recovery, utilization, and environmental effects, pp. 1-19.

Vrontisi, Z., Charalampidis, I., Lehr, U., Meyer, M., Paroussos, L., Lutz, C., Lam-González, Y.E., Arabadzhyan, A., González, M.M. and León, C.J., 2022. Macroeconomic impacts of climate change on the Blue Economy sectors of southern European islands. Climatic Change, Vol. 170 No. 3, p. 27.

Wan, Z., El Makhloufi, A., Chen, Y. and Tang, J., 2018. Decarbonizing the international shipping industry: Solutions and policy recommendations. Marine pollution bulletin, Vol. 126, pp.428-435.

Wang, T., Qu, Z., Yang, Z., Nichol, T., Clarke, G. and Ge, Y.E., 2020a. Climate change research on transportation systems: Climate risks, adaptation and planning. Transportation Research Part D: Transport and Environment, Vol. 88, p. 102553.

Wang, X., Yuen, K.F., Wong, Y.D. and Li, K.X., 2020b. How can the maritime industry meet Sustainable Development Goals? An analysis of sustainability reports from the social entrepreneurship perspective. Transportation Research Part D: Transport and Environment, Vol. 78, p. 102173.

Woo, J.K., Moon, D.S. and Lam, J.S.L., 2018. The impact of environmental policy on ports and the associated economic opportunities. Transportation Research Part A: Policy and Practice, Vol. 110, pp. 234-242.

Wu, X., Zhang, L. and Yang, H.C., 2020. Integration of eco-centric views of sustainability in port planning. Sustainability, Vol. 12 No. 7, p. 2971.

Yeremenko, K., 2022. International Maritime Organization and Decarbonization of Maritime Industry: Mandate and Instruments. Lex Portus, Vol. 8, p. 30.

Zhang, Y., Sun, L., Ma, F., Wu, Y., Jiang, W. and Fu, L., 2022. Collaborative optimization of the battery capacity and sailing speed considering multiple operation factors for a battery-powered ship. World Electric Vehicle Journal, Vol. 13 No. 2, p. 40.

Zhang, Y., Yang, X., Brown, R., Yang, L., Morawska, L., Ristovski, Z., Fu, Q. and Huang, C., 2017. Shipping emissions and their impacts on air quality in China. Science of the Total Environment, Vol. 581, pp. 186-198.

Zhen, L., Zhuge, D., Murong, L., Yan, R. and Wang, S., 2019. Operation management of green ports and shipping networks: overview and research opportunities. Frontiers of Engineering Management, Vol. 6 No. 2, pp. 152-162.

Zhmur, V.N. and Leonov, V.Y., 2018. WAYS TO INCREASE ECONOMIC, ENERGY EFFICIENCY AND ENVIRONMENTAL SAFETY OF SEA FREIGHT. American Scientific Journal, Vol. 19, pp. 15-22.