

Bibliometric Analysis of Sustainable Green Maritime Research with Visual Mapping Technique

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Abstract

In coastal countries, the maritime industry has a structure that complements and strengthens the sectors it is connected to, and its ties to tourism are growing stronger every day. In today's world, where the value of green maritime practices is increasing, the collaborations of maritime transportation and tourism with related fields, their sustainability, and environmental sensitivity will contribute to the long-term development of these two industries. The aim of this study is to examine the research on green maritime studies using visual mapping technique and bibliometric analysis. In this context, Web of Science (WOS) Core Collection database was used to analyze scientific publications in the field of green maritime and searches were made with the keyword "Green Maritime". Based on the search results, the most influential articles, countries, authors and titles were identified, and citation, word mining and bibliometric matching analyses were performed using VOSviewer software. The research findings reveal the distribution of studies in the field of green maritime studies by year, publication categories, authors

with the most publications and the most cited articles. According to the results of the analysis, "China, Denmark and Norway" stand out among the countries that publish the most in this field. Among the universities with the highest number of publications are "Technical University of Denmark", "Dalian Maritime University" and "Shanghai Maritime University". In the study, a word map and co-authorship map of green maritime literature were also created. While keywords such as "green maritime logistics", "maritime transport" and "speed optimization" stand out in the word map, the co-authorship map shows the prevalence of international collaborations. This study provides theoretical contributions to related fields and offers data to support strategies for advancing sustainable maritime practices.

Keywords: Maritime Tourism, Maritime, Green Maritime, Maritime Transport, Sustainable Maritime, Sustainability.

JEL Codes: L83, L91, Q56

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Introduction

Maritime transportation in international trade is of great importance as the lifeblood of the global economy. Around 90% of global trade is conducted via maritime transportation (Wang et al., 2023). In this context, the role of ships stands out as a critical element in ensuring the flow of trade goods and supporting economic growth (Caliskan & Ozturkoglu, 2018). Advanced technologies, trained personnel and effective maritime management are required for ships to carry out their activities safely. However, the environmental impacts of the maritime industry have posed significant sustainability challenges. Due to the negative impacts of maritime transportation on greenhouse gas emissions, ocean pollution and biodiversity (Song et al., 2023), sustainable maritime practices and green shipping concepts are becoming increasingly important (Shin et al., 2018). Green maritime refers to the adoption of environmentally friendly practices in various areas such as shipbuilding, fuel utilization, operational processes and waste management. In this context, green shipping aims to reduce the carbon footprint of ships, prevent marine pollution and increase environmental sustainability in general. For example, the use of low-sulfur fuels, energy-efficient ship designs and proper waste management are among the key elements of green maritime. Sustainability in the maritime industry is also supported by international regulations and policies. Emission reduction targets set by the International Maritime Organization (IMO) and other environmental regulations are among the important steps to promote green maritime (IMO, 2023). These policies require all stakeholders in the sector to adopt sustainable practices and fulfill their environmental responsibilities (Mjelde et al., 2019). The importance of maritime transportation in international trade and the value of green maritime practices in terms of sustainability make it possible to link it with the tourism industry. Especially, incorporating maritime tourism vehicles into international policies and regulations alongside the maritime industry strengthens the bond between the two by adopting green practices in both the maritime and tourism sectors. Ensuring that tourists, an important part of tourism, reach their destinations safely and in an environmentally friendly manner, instilling environmental awareness, prioritizing environmentally sustainable practices, protecting destinations, transportation routes, and biodiversity, and reducing the negative impacts of maritime transportation will contribute positively to both industries. Indeed, Baddollahi et al. (2022) define sustainability as a shared responsibility and recommend adopting green practices and increasing environmental awareness in the development of maritime tourism.

The purpose of this study is to reveal the importance of the concept of green maritime in international trade and its contributions to sustainable maritime

transportation and to conduct a bibliometric analysis based on the studies conducted in this field and to examine the existing literature. In particular, to review the number and scope of scientific studies assessing the effectiveness and prevalence of green maritime practices and to identify new insights and perspectives that these studies provide to the literature. In the literature, it is seen that various studies have been conducted on green maritime. In their study, Tadros et al. (2023) addressed the main factors that directly affect the operational efficiency, fuel consumption and emission release of ships within the framework of green maritime. In this context, they analyzed the studies between 2010 and 2022 through the Scopus database. Davarzani et al. (2016) conducted a bibliometric analysis using Scopus database for studies on maritime, port, logistics, green, sustainable and green operations, etc. within the scope of green maritime and green ports between 1975-2014. Ampah et al. (2021) bibliometrically analyzed the studies on clean alternative marine fuels within the scope of green maritime between 2000-2020 using Scopus and Web of Science (WOS) databases. It is seen that bibliometric analysis studies on green maritime generally focus on studies on issues that will indirectly affect green maritime. In this study, the studies directly accessed through the green maritime keyword were examined bibliometrically. This study identifies the current state of research in the field of green maritime research and future research directions and makes important contributions to the literature. The findings provide data that will help to develop strategies to increase sustainability in the maritime and tourism industry and green maritime policies.

Sustainability and Green Maritime

Sustainability is the concept of meeting our current needs while leaving a world in which future generations can meet their own needs. It aims to improve the lives of today's people and future generations, to ensure that they live in prosperity and peace, and to create a livable environment (Kara, 2023). From this perspective, sustainability covers issues such as the efficient and fair use of resources, prevention of pollution, control of carbon emissions and combating climate change in order to leave a livable world for future generations (Tezcan, 2023). The concept of sustainability was first introduced in the 1987 Brundtland Report, which highlighted the critical balance between humanity's pursuit of a better quality of life and the limitations imposed by nature. Over time, this concept has evolved to encompass three key dimensions: social, economic, and environmental (Kuhlman & Farrington, 2010). While the environmental dimension requires reducing environmental impacts, the economic dimension is concerned with minimizing or sustaining costs. The social dimension

aims to improve the welfare of society, including by protecting human rights and improving labor regulations. It can be said that the main goal of sustainability is to reduce economic costs, minimize environmental impacts and improve social justice. In recent years, the maritime industry has been emphasizing sustainability (Shin et al., 2018). The maritime sector includes areas such as shipping, shipbuilding, port operations and maritime services and serves as a source of income for coastal destinations. In particular, shipping is an important component that enables the transportation of goods and products using vehicles such as ships and boats (Le et al., 2024). Similarly, maritime transportation, an important and complex component of passenger transport, has continued to be valued from past to present in both the tourism and hospitality sectors and the context of sustainable maritime sector (Hoarau-Heemstra et al., 2023; Paiano et al., 2020; Ruiz-Guerra et al., 2019; Véronneau & Roy, 2009). Therefore, sustainable operations in maritime transportation, which require multidisciplinary reviews, have become an important issue for companies in the maritime supply chain. In recent years, greenhouse gas emissions from maritime transportation have been a global concern. In this context, reducing fuel consumption and carbon footprint stands out as a strategic goal for maritime companies and the service sectors collaborating in this field (Onyango, 2025; Paiano et al., 2020; Ruiz-Guerra et al., 2019; Simonsen et al., 2019). Recreational activities conducted within the scope of maritime tourism (such as sea excursions, diving, etc.) are associated with risks such as moorings, antifouling (toxic paint), marine litter, invasive species, discharges (gray water, fuel, and oils), marine waste, manipulation, overfishing, etc., and directly and indirectly affect marine ecosystems (Caparrós-Martínez et al., 2022). Similarly, cruise ships, which are a significant component of maritime tourism, have become a popular means of vacation, travel, and recreational maritime transportation. Cruise shipping is described as a continuously growing maritime activity (Pallis & Vaggelas, 2019). However, the environmental impacts such as water, oil, and noise pollution resulting from the power systems of cruise ships are considered significant problems. To address these issues, it is proposed to develop environmentally friendly and sustainable ship technologies by utilizing solar energy, an inexhaustible and easily accessible renewable energy source (Shi & Luo, 2018). According to Pallis & Vaggelas (2019), it is emphasized that the "green" policies prioritized in the maritime industry are also inevitable for cruise ships. Despite continuing to grow as an economic activity, cruise ports, cruise lines, all relevant stakeholders, and destinations are associated with a number of environmental issues (e.g., footprints). Therefore, when examined from the perspective of both industries reducing environmental impact and increasing

fuel efficiency will contribute directly to maritime environmental sustainability and economic prosperity and indirectly to social sustainability (Mansouri et al., 2015). The main goal of sustainability in ports is to maximize profits while ensuring socially acceptable, safe, energy efficient and environmentally friendly management (Lim et al., 2019). There are also some barriers to sustainability in international shipping. Some of these include the difficulty of cooperation and partnerships due to the multi-regional nature of activities, different modes of transportation and logistics, making information sharing difficult. Lack of understanding of sustainability, green and sustainable terms, sustainability efforts are reactive and do not receive sufficient support from government, public and international platforms, and freight transportation data is limited or outdated (Wu et al., 2020). Carbon dioxide (CO₂) and other air contaminants trap sunlight and radiation in the atmosphere, causing heat to be trapped, which leads to an increase in the Earth's temperature. This situation, which emerges as a result of climate change, is defined as global warming. From this point of view, the concept of green maritime or sustainable maritime is an approach that envisages the use of ships that carry out the transportation of goods and passengers in the maritime and tourism industries with the lowest energy use and improve environmental conditions (Hoarau-Heemstra et al., 2023; Paiano et al., 2020; Ruiz-Guerra et al., 2019; Simonsen et al., 2019; Tadros et al., 2023). In other words, green shipping aims to prevent exhaust emissions from ships for the global ecosystem, as it means efficient maritime transportation with minimal damage to health and ecology (Shi et al., 2018; Wan et al., 2016). According to the Kyoto Protocol, the greenhouse gases that cause exhaust emissions and need to be controlled urgently are CO₂ and other air contaminants. CO₂ is responsible for the largest percentage of global warming due to its prevalence (Wang et al., 2023). This shows that CO₂ and other air pollutants released by ships into the atmosphere increase global warming and lead to climate change. Therefore, the concept of green maritime or sustainable maritime aims to reduce the environmental impact of ships by minimizing their energy use and prevent their negative impact on the global ecosystem.

Methodology

In this study, articles and papers on sustainable green maritime research were bibliometrically analyzed using the WOS Core Collection database. Word mining and visual mapping were then performed using VOSviewer 1.6.20 software. In this framework, 31 articles and five papers using the keyword "Green Maritime" from the WOS database and published between 2010 and May 2024 were bibliometrically examined with the VOSviewer program.

The WOS database is one of the most widely accepted and frequently used databases in the scientific literature for the easiest compilation of the data required for bibliometric analysis (Bozdemir & Çivi 2019; Yang et al., 2013). The concept of bibliometrics is defined as the examination of studies in different fields by combining mathematical and statistical methods. The term was first used by E. Wyndam Hulme at Cambridge University in 1922. Bibliometrics, derived from the words "biblio" and "metrics", comes from the Greek and Latin words "bybl(os)" meaning book and "metricus" or "metrikos" meaning measurement (Yorulmaz et al., 2022).

Scientific mapping methods and bibliometric analyses help to understand the development of the topic, providing a systematic guidance to researchers working in the related field. Such methods, quantify relevant countries, research areas, journals, publishing houses, organizations, universities, editors, authors, and keywords (Zhang et al., 2009). It also examines networks of attribution and association. These methods can be used to create node/link maps to visually observe research distribution, the direction of research development, and hotspots (Seyhan & Öztürk, 2021).

Findings

Distribution of publications on green maritime by years

The distribution of 36 publications accessed according to the search records using the keyword "Green Maritime" in the WOS database in May 2024 is shown in Figure 1.

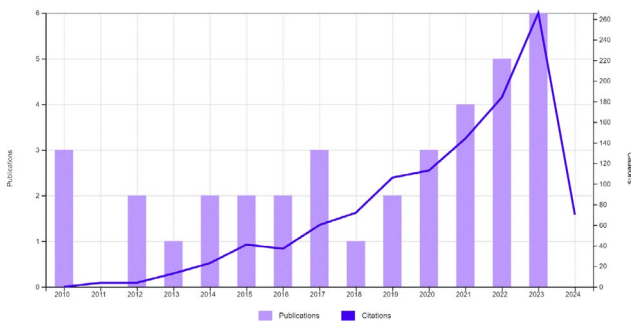


Figure 1. Distribution of Publications by Years

Looking at Figure 1, the highest number of six studies was published in 2023. It is seen that five studies were published in 2022, four in 2021, three in 2010, 2017 and 2020, two in 2012, 2014, 2015, 2016 and 2019, one in 2013 and 2018, and no study was published in 2011 and the first five months of 2024.

Distribution by publication category

The WOS database also allows publications to be

analyzed according to their categories. Figure 2 shows the top 10 publications in the WOS database according to publication categories.



Figure 2. Distribution of Publications by Category

The categorization of all publications in the WOS database is shown in Table 1.

Table 1. Distribution of Publications by Category

WOS Category	Number of Publications	% Distribution
Transportation Science Technology	13	36.111
Green Sustainable Science Technology	9	25.000
Environmental Sciences	8	22.222
Environmental Studies	8	22.222
Transportation	8	22.222
Energy Fuels	4	11.111
Engineering Environmental	4	11.111
Engineering Electrical Electronic	3	8.333
Management	3	8.333
Engineering Civil	2	5.556
Engineering Marine	2	5.556
Oceanography	2	5.556
Operations Research Management Science	2	5.556
Telecommunications	2	5.556

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Business	1	2.778
Chemistry Multidisciplinary	1	2.778
Construction Building Technology	1	2.778
Economics	1	2.778
Engineering Multidisciplinary	1	2.778
Engineering Ocean	1	2.778
Forestry	1	2.778
Geography	1	2.778
Marine Freshwater Biology	1	2.778
Materials Science Multidisciplinary	1	2.778
Materials Science Paper Wood	1	2.778
Water Resources	1	2.778

When Figure 2 and Table 1 are examined, the highest number of publications were made in the fields of transportation science technology with 13 publications, green sustainable science technology with nine publications, environmental sciences, environmental studies and public transportation with eight publications, energy fuels, engineering environment with four publications, engineering electrical electronics and management with three publications, and engineering construction with two publications.

Journals with the most publications

The journals with the highest number of publications according to WOS database data are shown in Table 2.

Table 2. The Journals in Which the Publications Are Most Frequently Published

Journal Name	Number of Publications	% Distribution
Transportation Research Part D Transport and Environment	5	13.889
Journal of Cleaner Production	3	8.333

Sustainability	2	5.556
Transportation Research Part C Emerging Technologies	2	5.556
Advanced Materials Research	1	2.778
Benchmarking An International Journal	1	2.778
Energy Research Social Science	1	2.778
Engineering Technology Applied Science Research	1	2.778
Environment Development and Sustainability	1	2.778

When Table 2 is examined, it is seen that the journal "Transportation Research Part D Transport and Environment" ranks first with five publications among the 9 journals with the highest number of publications. The others are "Journal of Cleaner Production" with three publications, "Sustainability" and "Transportation Research Part C Emerging Technologies" with two publications, "Advanced Materials Research" with one publication, "Benchmarking An International Journal", "Energy Research Social Science", "Engineering Technology Applied Science Research" and "Environment Development and Sustainability".

Authors with the most publications and most cited publications

The five most cited authors are shown in Table 3.

Table 3. Top Five Authors and Number of Publications

Author	Number of publications
Kontovas, Christos A.	3
Psaraftis, Harilaos N.	3
Laporte, Gilbert	2
Gribkovskaia, Irina	2
Ma, Dongfang	2

When Table 3 is analyzed, the authors with the most publications are "Kontovas, Christos A." and "Psaraftis, Harilaos N." with three publications. The authors of the two publications are "Laporte, Gilbert", "Gribkovskaia, Irina" and "Ma, Dongfang".

Table 4 contains the citation counts of the most cited publications.

Table 4. The Most Cited Publications

Number	Author	Year	Annual Average Citation	Total Citation
1	Psaraftis & Kontovas	2014	81.64	1143
2	Psaraftis & Kontovas	2010	12.47	187
3	Venturini et al.	2017	15.88	127
4	Fang et al.	2019	24.8	124
5	Kontovas	2014	6.55	72
6	Schinas & Stefanakos	2012	5.23	68
7	Yu et al.	2021	11	44
8	Norlund et al.	2015	3.2	32
9	Stevens et al.	2015	3.1	31
10	Ma et al.	2021	7	28

According to the data in Table 4, "Ship speed optimization: concepts, models and combined speed-routing scenarios" with 1143 total citations. Others; "Balancing the economic and environmental performance of maritime transportation" with 187 citations, "The multi-port berth allocation problem with speed optimization and emission considerations" with 127 citations, "Toward future green maritime transportation: an overview of seaport microgrids and all-electric ships" with 124 citations, "The green ship routing and scheduling problem (GSRSP): a conceptual approach" with 72 citations, "Cost assessment of environmental regulation and options for marine operators" with 68 citations, "Literature review on emission control-based ship voyage optimization" with 44 citations, "Supply vessel planning under cost, environment and robustness considerations" with 32 citations and "Is new emission legislation stimulating the implementation of sustainable and energy-efficient maritime technologies?" publications with 31 citations.

Top 10 most cited articles according to WOS results

When the most cited studies are examined by year, significant insights into the evolving impact and

popularity of research over time can be observed. For example, Psaraftis & Kontovas (2010) examined the effects of various maritime emission reduction policies on maritime logistics and the important trade-offs that these policies bring. Basically, they addressed the relationships between the environmental benefits of these measures and the economic aspects of the logistics chain. They stated that the three main ways to reduce maritime GHG emissions are technical measures (alternative fuels, energy-efficient engines, more efficient ship hulls etc.) market-based instruments (emissions trading and carbon tax) and operational options (speed optimization, optimised routing, fleet planning, etc.). The study specifically investigated the potential impacts of speed reductions and changes in fleet size on logistics characteristics such as transit inventory costs. They also addressed the risk that measures that increase shipping costs could shift traffic to more environmentally harmful land transportation. They emphasized that some measures implemented to achieve environmental objectives may have serious side effects on the economics of the logistics supply chain and that these effects should be carefully evaluated. In this context, they concluded that there is a need to balance maritime logistics impacts with environmental policies. Building on the theme of balancing economic and environmental considerations, Schinas & Stefanakos (2012), presented a model based on stochastic linear programming for the assessment of high operating costs incurred in sulfur emission control areas of ships. This model determines the fleet mix and the capacity offered, aiming to minimize the total cost to operators. In study, they examined the costs and efficiency impacts of different ship types under various scenarios. They emphasized the cost-increasing effects of low sulfur fuel consumption in the sulfur emission control zone. They aimed to reveal how the current regulations will change ship operating costs and how these costs will affect the distribution of the fleet. Psaraftis & Kontovas (2014) aimed to develop various speed optimization models by addressing critical issues related to ship speed optimization. They focused on models that include basic parameters such as fuel price, market situation, inventory cost of cargo and the dependence of fuel consumption on carrying capacity, which affect the speed decision of the ship owner or charterer. They conclude that solutions for optimal environmental performance do not always coincide with solutions for optimal economic performance, and that policies that appear at first glance to be environmentally appropriate may in fact be inappropriate. Considering that a private operator will choose the optimal economic performance, policy makers have suggested that measures such as fuel taxes, etc. should be introduced and incentivized by policy makers to achieve more environmentally and socially favorable outcomes. They

emphasized that in this case, more favorable results can be obtained for the benefit of the environment and society in terms of CO₂ production. In contrast, the study conducted by Kontovas (2014) highlighted how the scope of ship routing and reporting issues can be addressed, emphasizing the importance of speed variation in reducing emissions. The research explored various methods for estimating fuel consumption and emissions, ultimately concluding that increasing ship speed could lead to improved performance.

Norlund et al. (2015) examined the planning of supply ships delivering cargo on oil and gas platforms. They developed a simulation-optimization methodology that takes into account costs, environmental impacts and operational robustness. They concluded that speed optimization can reduce fuel consumption and hence emissions, but these strategies will affect the robustness of weekly ship schedules due to increased weather uncertainty during the winter season. Similarly, Stevens et al. (2015), They investigated whether new emission laws encourage the implementation of sustainable and energy efficient marine technologies. They have developed a framework that links emission laws in different countries and the technical energy efficient solutions that can be used to comply with these laws. It was emphasized that the Energy Efficient Design Index (EEDI), instead of encouraging the use of new ship engine technologies or alternative fuels, directs shipping companies to order ships that reduce design speed, and the Ship Energy Efficient Management Plan (SEEMP) encourages companies to switch to bi-fuel engine systems instead of switching completely to alternative energy systems. The paper analyzes the feasibility of these policies and quantitatively assesses their impact for existing ships and newbuildings.

These studies highlight the importance of achieving a balance between economic performance and environmental benefits by focusing on ship speed optimization and emission reduction. Similarly, Venturini et al. (2017) addressed the issue of assigning berth times and positions to ships at container terminals and developed a novel model that incorporates ship speed optimization and environmental impacts. With this model, they aimed to reduce fuel consumption, total operation time and emissions by optimizing the cruising speed of ships between ports. They concluded that by applying the model, fuel consumption and air emissions can be reduced by about 40%. They emphasized that this requires strong cooperation between shipping lines and terminal operators.

Fang et al. (2019) investigated how port microgrids

and fully electric ships can drive green energy transformation in maritime operations. They emphasized the significant advantages these technologies offer, such as superior control features, enhanced energy efficiency, and greater flexibility in both electricity management and logistics. Their work highlights the potential of these innovations to revolutionize sustainability practices at sea. Extending the focus on green maritime solutions, Yu et al. (2021), focused on fuel consumption reduction and emission control based on ship voyage optimization. In the study, they aimed to make ship operations more efficient in line with the development of green maritime transportation by examining the factors affecting fuel consumption. They emphasized the importance of travel optimization based on emission control and highlighted the theoretical foundations of hydrodynamic factors affecting fuel consumption and optimization models. Building upon these themes, Ma et al. (2021) aimed to develop a model that includes multi-objective optimization of ship route and speed. With the model, they aimed to minimize both transportation costs and emissions, taking into account emission control area regulations. This optimization model is an attempt to balance transportation costs with the reduction of CO₂ and SO_x emissions while selecting the ship route and speed. As an example, they studied a route from Halifax in Canada to Georgia in the United States of America (USA). In the study, they concluded that both the total costs and emissions of the ship decreased and the total costs did not increase despite the increases in fuel prices.

Top publishing countries and universities by articles published on green maritime

Table 5. Top Five Countries with the Most Publications

Country	Number of publications
China	13
Denmark	5
Norway	5
Canada	3
Singapore	3

When Table 5 is analyzed, the country with the highest number of publications is China with 13 publications. "Denmark" and "Norway" with five publications and "Canada" and "Singapore" with three publications are the other countries with the highest number of article publications.

Table 6. Universities with the most publications

University	Number of publications
Technical University of Denmark	4
Dalian Maritime University	3
Shanghai Maritime University	3
Zhejiang University	3
Wuhan University of Technology	2
Hec Montreal	2
Molde University College	2
Nanyang Technological University	2
Universite De Montreal	2

When Table 6 is analyzed, "Technical University of Denmark" is the university that published the most articles with four publications. "Dalian Maritime University", "Shanghai Maritime University" and "Zhejiang University" with three publications and "Wuhan University of Technology", "Hec Montreal", "Molde University College", "Nanyang Technological University" and "University De Montreal" with two publications are the other universities with the most article publications.

Word map of Green Maritime literature

VOSviewer shows nodes, links and clusters in two-dimensional graphs. The nodes appear as labeled circles and their size indicates how often these elements occur. The distance between nodes indicates the closeness of their relationship. Closer distances indicate that the elements are more relevant. Nodes are clustered by color and show the relationships between links by line thickness. A thicker line indicates a stronger relationship, while a thinner line indicates a weaker relationship (Petrović & Thomas, 2024).

Keyword clusters for peer word analysis

Keyword clusters in the synonym analysis reveal the frequency with which keywords are used together. This review provides researchers with an insight into the conceptual framework of previous studies and helps them understand the scope and focus of research in the field.

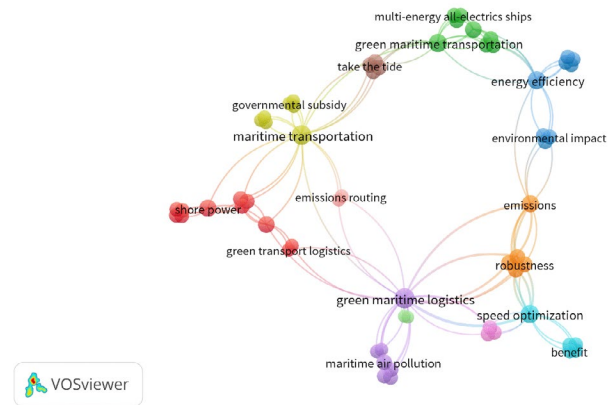


Figure 3. Green Maritime Keyword Clusters Co-Word map

When Figure 3 is examined, it is shown with a map of 132 keywords that occur at least "1" time in the studies published on Green Maritime and are related to each other. "Green maritime logistics", which was used "9" times, was the most used keyword. The others are listed in descending order according to the number of times they are used: "maritime transport" "speed optimization" "emissions" "green maritime transport" "energy efficiency" "marine air pollution" "vessel routing and scheduling" "supply vessel operation" "weather uncertainty". In terms of connectivity, "green maritime logistics" is again in the first place with 32 connectivity, followed by "maritime transport" and "speed optimization" with 19 connectivity. This is followed by "emissions" with 15 link strengths and "green maritime transport" with 14 link strengths.

Word cloud of abstracts of green maritime studies

The word cloud provides researchers with an overview of the abstract structure of previous studies on a topic and helps them to identify topics to focus on. In this study, the abstracts of 36 published studies on green maritime using the WOS database were analyzed with the Maxqda 2024 program. A word cloud was created using words that appeared at least three times in the abstracts and is shown in Figure 4.



Figure 4. Summary Word Cloud of Green Maritime studies

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Among the words shown in Figure 4 and frequently used in the summaries; "maritime" was used 95 times, "ship" 46 times, "green" 42 times, "transport" 36 times, "port" 18 times, "environmental", "industry", "transport" and "transportation" 15 times, "energy" and "sustainable" 14 times and "supply" 13 times.

Map of co-authorship

Co-authorship is defined by how often two documents are cited together in new articles. By citing

two previous articles together, the author of a new article creates a co-citation link between these two old articles. In basic terms, co-authorship is considered a measurable link between two papers (Griffith et al., 1974).

Co-authorship map of countries

The co-authorship relationships of the joint publications made by different countries on the subject are shown in Figure 5 and the total link strength of the publications made by countries is shown in Table 7.



Figure 4. Summary Word Cloud of Green Maritime Studies

Links in the map show other clusters related to a cluster. The number of co-authorships that researchers from one country have with researchers from another country is called total linkage strength (Yorulmaz & Derici, 2024; Van Eck & Waltman, 2017).

According to the country co-authorship map shown in Figure 5;

Table 7. Total Connection Strength of Countries' Broadcasts

Country	Number of publications	Co-authorship total link strength
China	13	6
Canada	3	4
England	2	3
Ghana	1	2
Netherlands	2	2
Singapore	3	2
Denmark	5	1
Germany	2	1
Greece	2	1
Malaysia	1	1
Norway	5	1
Pakistan	1	1
Philippines	1	1
Poland	1	1
Portugal	1	1
Vietnam	1	1
Indonesia	1	1

When Table 7 is analyzed, according to the co-authorship map of the countries, China ranked first with a total link strength of "6" and 13 publications. Canada ranked second with "4" total connection strength and "3" broadcasts, while the UK ranked third with "3" total connection strength and "2" broadcasts. The next ones are Ghana with "2" total connection strength and "1" broadcast, Netherlands with "2" total connection strength and "2" broadcast, Singapore with "2" total connection strength and "3" broadcast.

Co-citation matching of authors

It is the examination of other authors cited by the same author. It shows the frequency with which two authors' works are cited together and thus measures the level of citation linkage between authors. Table 8 shows the top 10 authors according to the number of citations on green maritime, taking into account the total link strength. All authors are also shown in Figure 6.

Table 8. Authors' Number of Citations and Total Link Strength

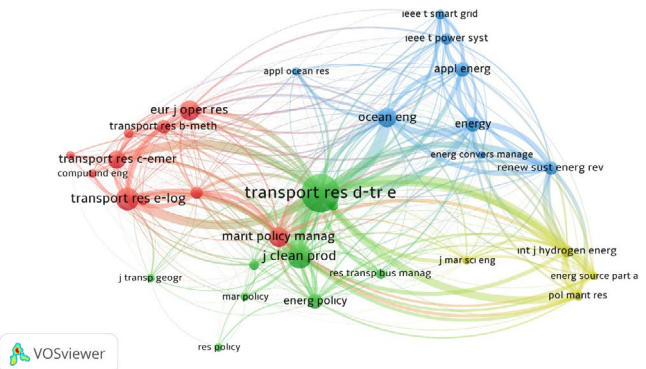
Country	Number of publications	Co-authorship total link strength
China	13	6
Canada	3	4
England	2	3
Ghana	1	2
Netherlands	2	2
Singapore	3	2
Denmark	5	1

Germany	2	1
Greece	2	1
Malaysia	1	1
Norway	5	1
Pakistan	1	1
Philippines	1	1
Poland	1	1
Portugal	1	1
Vietnam	1	1
Indonesia	1	1

England	2	3
Ghana	1	2
Netherlands	2	2
Singapore	3	2
Denmark	5	1

The co-citation map of journals is shown in Figure 7.

Figure 7. Co-Citation Map of Journals



When Table 8 is analyzed, "Psarftis" ranked first with 481 total connection power in the ranking based on total connection power. The others are "Fagerholt" and "Kanellos" with 367 total connection strength, "International Maritime Organization (IMO)" and "Zhen" with 331 total connection strength, "Lindstad" with 298 total connection strength, "Hoang" with 285 total connection strength, "Wang" with 279 total connection strength, "Fernando" and "Zhu" with 276 total connection strength.

When Table 9 and Figure 7 are examined, the most cited journal with 109 citations is "Transportation Research Part D Transport and Environment". The others are "Journal of Cleaner Production" with 54 citations, "Transportation Research Part E: Logistics and Transportation" with 47 citations, "Maritime Policy & Management" and "European Journal of Operational Research" with 38 citations, "Ocean Engineering" with 37 citations, "Transportation Research Part C Emerging Technologies" with 32 citations, "Energy" and "Energy policy" with 24 citations and "Applied Energy" with 23 citations.

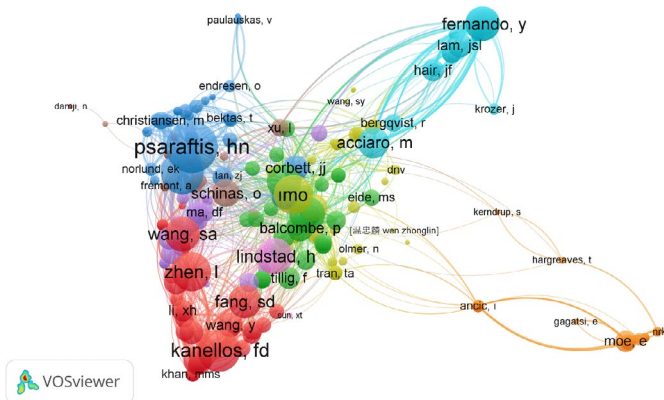


Figure 6. Co-Citation Map of Authors

The co-citation map in Figure 6 was created by considering authors with at least "2" citations and 236 authors met this condition.

Co-citation matching of journals

It shows the number of times two journal publications are cited together. Journals and the number of citations are shown in Table 9.

Table 9. Citation Numbers of Journals

Country	Number of publications	Co-authorship total link strength
China	13	6
Canada	3	4

The most emphasized topics of publications on green maritime issues

The most emphasized topics of the publications on green maritime are shown in Table 10.

Table 10. The most emphasized topics of the publications

Subjects	Number of publications
Supply Chain and Logistics	23
Power Systems and Electric Vehicles	3
The Science of Sustainability	2
Management	2
Environmental Sciences	2

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Paper and Wood Materials Science	1
Digital Signal Processing	1
Safety and Maintenance	1
Economy	1

Table 10 is analyzed, it is seen that the most emphasized topic in the publications is "supply chain and logistics".

Research method, analysis technique, data collection technique in the studies conducted

The research method, analysis technique and data collection technique of the top 10 most cited articles according to WOS results are shown in Table 11.

Table 11. Research Method, Analysis Technique, Data Collection Technique of Publications

Studies	Research Methodology	Analysis Technique	Data Collection Technique
1	A literature review was conducted as a research method.	Hardware-in-the-Loop experiments were applied.	Literature review, technical data and records from specific port microgrids and fully electric ships
2	Extended models and scenarios are derived for the economics and growth of ship speed and fleet development. These scenarios allow to analyze the relationships between ships' fuel consumption, emissions and logistical changes.	The study has created scenarios that provide changing data and decisive effects, and analyzed these scenarios.	-
3	Systematic programming and dynamic programming programs were used.	Ship speed variation has been analyzed using dynamic programming programs and comprehensive models.	Existing models and theoretical details from the literature on total speed diversity were utilized. The data required for fuel consumption and cost planning were obtained from previous studies and documents related to ship operations.
4	It formulated the green ship routing and scheduling problem by reviewing existing studies in the literature.	Various models in the literature were examined and analyzed how these models predict fuel consumption and emissions.	A literature review was conducted.
5	Literature review method was used.	The analysis was made by comparing and synthesizing the approaches and findings in the reviewed literature.	Data was collected through a systematic review of existing academic papers and reports covering fuel consumption, hydrodynamic factors, optimization models and emission control measures.

6	Stochastic Verification Programming was used. A model aiming to minimize the cost with analysis technology has been developed and it is aimed to unify the fleet management of ship operators under various scenarios.	A data set was created by bringing together the findings of previous research in the literature, summaries of technical reports and sources providing information on international maritime regulations. This data provided various parameters such as ship types, fuel costs, operating costs and scenarios to users in the sulfur emission control region.	A data set was created by bringing together the findings of previous research in the literature, summaries of technical reports and sources providing information on international maritime regulations.
7	A simulation-optimization based method has been developed for the supply ship. With this method, the weekly schedules of the supply ship were created by taking into account cost, emission and robustness factors.	A discrete event simulation model was used to simulate the effects of weather conditions on navigation and service times. In order to ensure cost efficiency for the ships, ship sailings and starting days were determined using a set covering model with a cost minimization objective. Speed optimization was applied to reduce travel times and associated fuel consumption.	Data from Statoil, a Norwegian oil and gas company, were used. Weather data taken from the Norwegian Meteorological Institute. These data also include wave height observations at 14 locations in the North Sea at three-hourly intervals from 1957 to 2013.
8	Emission laws in different countries and technical efficient solutions that can be used to comply with the laws have been investigated.	A framework analysis has been conducted linking emission policies and new marine technologies.	Various reports, scientific articles, and studies were reviewed.
9	A mathematical model has been developed to optimise the cruising speed of container ships between ports, thereby reducing fuel consumption and emissions.	An optimization model was created using mixed integer programming (Integer Linear Programming-ILP). In the model, optimization was performed using certain speed ranges.	The data is collected from existing literature on berth allocation problems and ship speed optimization studies.
10	A mathematical modeling and simulation method is used for multi-objective optimization of ship route and speed.	Non Dominant Sorting Genetic Algorithm II (NSGAI) and the Technique for Preference Ranking by Similarity to Ideal Solution (TOPSIS) methods were used.	Real data on the ship's route and speed were used. Ship performance parameters, fuel prices, weather data are used in the study.

When Table 11 is examined, it is seen that the articles generally provide data through literature review. The publications in the table are respectively; "Toward Future Green Maritime Transportation: An Overview of Seaport Microgrids and All-Electric Ships", "Balancing the economic and environmental performance of maritime transportation", "Ship speed optimization: Concepts, models and combined speed-routing scenarios", "The Green Ship Routing and Scheduling Problem (GSRSP): A conceptual approach", "Literature review on emission control-based ship voyage optimization", "Cost assessment of environmental regulation and options for marine operators", "Supply vessel planning

under cost, environment and robustness considerations", "Is new emission legislation stimulating the implementation of sustainable and energy-efficient maritime technologies?", "The multi-port berth allocation problem with speed optimization and emission considerations" and "Green maritime: a routing and speed multi-objective optimization strategy" is in the form of.

Conclusion and Contributions

The increasing importance of maritime transportation in international trade necessitates the adoption of environmentally friendly and sustainable practi-

ces. Sustainable green maritime is a critical approach for a cleaner and healthier world by minimizing the environmental impact of the maritime sector. In this study, it is aimed to examine the researches conducted in the field of green maritime by using bibliometric analysis method and visual mapping techniques. Using the WOS database, the most influential articles, authors, countries and journals in this field were identified.

The research findings show that studies on green maritime studies, although fluctuating, have generally increased over the years and are concentrated especially in countries such as China, Denmark and Norway. Among the universities with the highest number of publications are "Technical University of Denmark", "Dalian Maritime University" and "Shanghai Maritime University". In addition, the most commonly used keywords and topics in the literature were also identified, and topics such as "green maritime logistics", "speed optimization" and "emissions" were found to be prominent. This situation shows that especially maritime transportation, reduction of greenhouse gas emissions in transportation, and the effects of ship speed on emissions during transportation have been investigated. It also shows the necessity of reducing CO₂ emissions and achieving sustainable green maritime in the maritime industry.

Sustainability in the maritime industry not only provides environmental benefits, but also offers a broader perspective, taking into account economic and social dimensions. This also reflects the implications encompassing all maritime components, primarily passenger transportation in coastal destinations. Therefore, sustainability in the maritime industry, based on multidisciplinary reviews, constitutes important steps that add value to the sustainability of all areas directly and indirectly connected, including the tourism and hospitality industry. So much so that maritime transportation is a significant motivator in tourists' travel preferences. In the investment plans of coastal countries, the maritime industry, which is prioritized for the economic development of maritime tourism destinations, consists of ports, ships, ship operations, shipyards, maritime transport companies, suppliers, and other intermediary services. Consequently, investments in coastal countries are shaped by opportunity costs, and sectoral developments that contribute to the development of cities and regions progress accordingly. For example, in passenger transportation (cruise ships, yachts, sailboats, and other maritime tourism vehicles, sea buses, ferries, cruise lines, cruise ports, marinas, piers, docks, etc.) and in freight transportation (tankers, container ships, Ro-Ro ships, bulk carriers, cargo ships, ports, shipyards for maintenance and repairs, etc.), there is a distinct sectoral operation. Therefore, the term "sustainable green maritime" should not be considered as a specific area. It is an impor-

tant component of international trade that contributes to all areas connected with maritime transportation, integrates with each other, values management and operations, and emphasizes sustainability. In the long term, sustainable green maritime practices will also have positive outcomes in areas such as cost savings, operational efficiency, service quality, and public health. Sustainable green maritime, increasing energy efficiency, use of renewable energy sources, waste management and adoption of environmentally friendly technologies are important steps to improve environmental performance in the sector. In addition, international regulations and policies play a major role in promoting sustainable green maritime practices. For instance, IMO has included strategic targets for green maritime by taking into account sustainable development (IMO, 2023). Indeed, Maersk ECO Delivery has designed a sustainable service by taking the initiative in the use of environmentally friendly fuels in the field of green shipping in the world (Maersk Line, 2022).

There are many studies in the literature in the maritime field (Ampah et al., 2021; Le et al., 2024). Among these studies, there are also studies carried out within the scope of green maritime (Davarzani et al., 2016; Fang et al., 2019; Ma et al., 2021; Mjelde et al., 2019; Song et al., 2023). For example, in the study conducted by Tadros et al. (2023), they conducted a bibliometric analysis to identify technologies and methods to reduce fuel consumption and exhaust emissions within the framework of sustainable green maritime. Accordingly, they focused on the main factors that have a direct impact on ship performance, exhaust emissions and fuel consumption. Within the scope of the analysis, three keywords, namely engine technologies, propeller selection and alternative fuels, were identified and studies between 2010 and 2022 were analyzed in the Scopus database. They concluded that no single solution is sufficient to achieve maritime sustainability, but a combination of various techniques can improve energy efficiency. Similarly, WOS database and VOSviewer were used in the study. Green maritime covers a broader spectrum, while clean alternative marine fuels address more specific issues. China, Denmark and Norway are the countries that stand out in this study. Time frames vary. Ampah et al. (2021) examined the studies on clean alternative marine fuels within the scope of green shipping between 2000-2020 using Scopus and WOS database. The use of the WOS database in this study is similar to the use of bibliometric analysis and visual mapping techniques. The use of "alternative marine fuels" as a keyword differs in terms of the different time period. While our study analyzed sustainable green maritime research, this study focused on clean alternative marine fuels. In the field of sustainable green maritime, China, Denmark and Norway countries and logistics and speed optimization came to the forefront, while in the

field of alternative fuels, the USA as a country and alternative fuels such as methanol, LNG, ammonia and hydrogen came to the forefront. Visual mapping also varies using the R-studio bibliometrix package.

Theoretical contributions

Upon reviewing the literature, there are maritime studies that support sustainable maritime tourism (Di Vaio et al., 2020; Frković et al., 2024; Ng et al., 2019; Simonsen et al., 2019; Zanobetti et al., 2023). Similarly, there are tourism studies that support maritime studies within the context of green maritime, with recommendations for sustainable maritime tourism, green ships, green practices, and sustainable practices (Badollahi et al., 2022; Caparrós-Martínez et al., 2022; Onyango, 2025; Paiano et al., 2020; Pallas & Vaggelas, 2019; Shi & Luo, 2018). This study highlights the connection between the concept of "green maritime" and tourism, emphasizing their shared common ground, and thus provides theoretical contributions to both maritime and tourism literature. Another common ground is the prominence of the maritime and tourism industries in Türkiye's development plans and economic revenue shares, with these two industries being prioritized in development goals and investment plans. Particularly, cruise tourism, one of the rapidly growing sectors in the tourism industry, is directly connected to maritime activities and serves as an important development tool for Türkiye. Therefore, it is recommended that green maritime practices be considered in coastal countries, and research be conducted from multidisciplinary perspectives, providing theoretical contributions.

A review of studies conducted in the field of green shipping in Türkiye reveals a predominant focus on energy efficiency, emission reduction, sustainable port management, and environmentally friendly maritime transportation (Altınpınar, 2025; Millet et al., 2021; Çelik & Yorulmaz, 2025). Academic institutions specialising in maritime studies, such as Istanbul Technical University, Istanbul University, and Dokuz Eylül University, have undertaken substantial research in this domain. The focus of these studies typically encompasses alternative fuel usage, carbon emission reduction, optimisation of ship operations, and green logistics strategies. In this context, the literature emphasizes common strategic objectives aimed at reducing the environmental damage caused by international maritime activities and proposes recommendations within this scope (Kurt, 2023; Millet et al., 2021). Studies evaluating green ports that promote sustainability also examine the current state and significance of green maritime practices in Türkiye (Çelik & Yorulmaz, 2025). Indeed, the IMO targets, which advocate for policies aimed at reducing maritime transport emissions to zero, have steered researchers toward this field. Challenges await-

ing shipowners, including financial and operational issues, access to new fuels, competitive pressures, and compliance with new regulations, have been identified (Altınpınar, 2025). The Port Operators Association of Türkiye (TURKLİM) is addressing the green transformation of ports, evaluating innovative ports within the framework of the zero-emission port concept (TURKLİM, 2024). There is a growing interest in ports that aim to contribute to environmental sustainability and improve working conditions through green port projects. Additionally, the potential of ports in Türkiye to achieve green port status is being actively evaluated (Keske et al., 2025). Research on green ports in Türkiye is becoming more diverse, with a strong emphasis on activities implemented to promote the use of sustainable energy (Demirci & Arıcan, 2024). In Türkiye, 20 ports hold "Green Port" certifications (TURKLİM, 2021). However, the effectiveness of green port practices is expected to improve, and the importance of increasing the number of such certified ports is frequently emphasized (Koşar Danışman & Özalp, 2016). Building on this, several recommendations can be made to provide a comprehensive analysis of green shipping research in Türkiye and to compare it with international literature. Firstly, bibliometric analyses on green shipping literature in Türkiye can be conducted to identify research trends and gaps in the field. This study provides an important basis for identifying current research trends, knowledge gaps and future research areas in the field of green maritime. It contributes significantly to understanding the current state of green maritime research and identifying future research directions. For instance, according to the research results, it is understood that the concepts highlighted in the word cloud (maritime, ship, green, environmental, shipping, industry, transportation, sustainability, transport, port, ship-owners, management, organization, sailing, voyage, cruise, etc.) need to be addressed. At the same time, it is clear that these concepts guide research in sustainable maritime and its related fields.

Practical contributions

Filling knowledge gaps and developing new strategies in this area will contribute significantly to enhancing environmental sustainability in the maritime industry. It is essential for maritime companies to have suitable tools to measure and evaluate their sustainable performance in economic, social, and environmental dimensions (Di Vaio et al., 2020; Zanobetti et al., 2023). Consequently, the maritime sector is expected to address the challenges and risks arising from increasing sustainability pressures. Additionally, examining Türkiye's maritime environmental policies and its compliance with international regulations would provide valuable insights for the advancement of sustainable maritime practices. In

addition, enhancing industry-academia cooperation could facilitate the development of more applicable and innovative solutions to current challenges in the sector. Conducting case studies on the implementation of green technologies in Turkish ports and ships can contribute to the literature by documenting local experiences and best practices. Finally, strengthening international cooperation with leading countries in green shipping, such as China, Denmark and Norway, would support the transfer of knowledge and technology, thus promoting Türkiye's progress in this area. This study, considering sustainable development goals, advocates for fostering collaborations on green maritime initiatives among maritime and tourism industries, as well as national and international organizations and institutions, to encourage maritime companies. In this context, expanding the scope of existing research in Türkiye and conducting more in-depth studies based on the proposed recommendations would make significant contributions to the green shipping literature and to the sustainable development of the maritime sector. Finally, this study makes important contributions to the development of new strategies and policies to improve environmental sustainability in the maritime sector and provides a reference point for research in all related areas, making significant contributions to both academia and industry.

Limitations and recommendations

The limitation of this study is that it only includes analyses based on the WOS database and does not include studies in other scientific databases. This may result in the analysis results not providing a complete overview. Another limitation is the limited number of publications analyzed in this study. This can make it difficult to generalize the analysis. Furthermore, the bibliometric analysis and visual mapping techniques used focused only on specific keywords, specific time periods and publications in specific languages and do not cover all research in the field of green maritime. It is recommended that future studies focus on more comprehensive and empirical research in areas related to the maritime industry, especially sustainable maritime tourism, where green practices are valued.

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