Received: 11.01.2024
Accepted: 18.03.2024
Published Online: 30.06.2024
DOI: 10.18613/deudfd.1418186
Research Article

Dokuz Eylül University
Maritime Faculty Journal
Vol:16 Issue:1 Year:2024 pp:1-21
E-ISSN: 2458-9942

NAVIGATING DECARBONIZATION: EXAMINING SHIPPING COMPANIES' FLEET MODERNIZATION STRATEGIES WORLDWIDE*

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ABSTRACT

The shipping industry's heavy reliance on fossil fuels has significantly contributed to global greenhouse gas emissions, necessitating urgent decarbonization measures. In this context, the trend towards environmentally friendly alternative fuels has accelerated and shipping companies has begun fleet modernization such as retrofitting vessels to accommodate alternative fuel systems or investing in new ships designed for specific alternative fuels. However, there are contradicting approaches in practice on viable option(s) to decarbonize. In this study, it is aimed to determine which strategies the shipping companies in fleet modernization mainly prefer. In this context, the current news under the title of "Shipping-Decarbonization" in the Thompson Reuters Refinitiv terminal has been scanned to seek answers about the direction in which the preferences of practitioners have evolved. Although there are different investment preferences, it has been determined that companies are predominantly investing in ships with methanol and LNG propulsion systems or retrofitting their existing fleets in this area on their decarbonization journey. Based on the analysis, this study aims to provide valuable insights for policymakers and industry stakeholders especially on identification of preferred alternative fuels in order to customize incentives and regulations aimed at encouraging the adoption of these particular alternative fuels

Keywords*: Shipping, Fleet Modernization, Alternative Fuels, Decarbonization.*

* The earlier version of this paper was presented in 1st International Maritime and Logistics Conference on 22-23 September 2023 in Zonguldak, Türkiye.

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KARBONSUZLAŞMADA YOL ALMAK: DÜNYA ÇAPINDA DENİZCİLİK ŞİRKETLERİNİN FİLO MODERNİZASYON STRATEJİLERİNİN İNCELENMESİ*

ÖZ

Denizcilik sektörünün fosil yakıtlara olan bağımlılığı, küresel sera gazı emisyonlarına önemli ölçüde katkıda bulunmuş ve acil karbonsuzlaştırma önlemleri alınmasını gerektirmiştir. Bu bağlamda, çevre dostu alternatif yakıtlara yönelik eğilim hız kazanmış ve denizcilik şirketleri, gemileri alternatif yakıt sistemlerine uygun hale getirmek veya belirli alternatif yakıtlar için tasarlanmış yeni gemilere yatırım yapmak gibi filo modernizasyonuna başlamıştır. Ancak, karbonsuzlaştırmaya yönelik uygulanabilir seçenek(ler) konusunda uygulamada çelişkili yaklaşımlar bulunmaktadır. Bu çalışmada, filo modernizasyonunda denizcilik şirketlerinin ağırlıklı olarak hangi stratejileri tercih ettiklerinin belirlenmesi amaçlanmaktadır. Bu kapsamda Thompson Reuters Refinitiv terminalinde "Shipping-Decarbonization" başlığı altında yer alan güncel haberler taranarak uygulayıcıların tercihlerinin ne yönde evrildiğine dair cevaplar aranmıştır. Farklı yatırım tercihleri olmakla birlikte, şirketlerin karbonsuzlaştırma yolculuğunda ağırlıklı olarak metanol ve LNG tahrik sistemli gemilere yatırım yaptıkları veya mevcut filolarını bu alanda güçlendirdikleri tespit edilmiştir. Bu çalışma, özellikle tercih edilen alternatif yakıtların belirlenmesi ve bu alternatif yakıtların benimsenmesine yönelik teşvik ve düzenlemelerin uygulanabilmesi için politika yapıcılar ve sektör paydaşları için değerli bilgiler sağlamayı amaçlamaktadır

Keywords: *Denizcilik, Filo Modernizasyonu, Alternatif Yakıtlar, Dekarbonizasyon.*

1. INTRODUCTION

Cargo ships are used to deliver nine out of ten traded items worldwide. The globalized society we live in today would not exist without shipping. However, the cargo ships required to travel tens of thousands of miles each day and consume outrageous amounts of fuel in order to transport products around the world. When ships, which are the sole element of maritime transportation, are compared with other transportation modes, although less carbon dioxide is emitted per ton-mile, the ecological impact is considerably higher due to the size of the scale. The fuel isn't the typical fuel that we use in our daily life. It is referred to as bunker fuel. Every ship in the world utilizes a liquid that resembles tar because it is inexpensive, but this cost has a significant drawback. It is extremely hazardous and filthy.

International Maritime Organization (IMO) as an international regulatory authority updated the International Convention for the Prevention of Pollution from Ships 73/78 (MARPOL) in 1997. The creation of MARPOL Annex VI, or Supplemental VI Regulations for the Prevention of Air Pollution from Ships, is the significant outcome of this amendment. However, MARPOL Annex VI initially mainly addressed rules and processes for designating NO_X and SO_X emission control areas, as well as emission control of air pollutants, NO_X and SO_X, and volatile organic compounds. The IMO did not incorporate marine greenhouse gas (GHG) emission mitigation into its regulatory framework until 2011.

The primary GHG, CO_2, is mostly responsible for the promotion of global warming. The ships are responsible for around 3% of global CO_2 emissions. For comparison, the maritime industry would be the sixth-largest global emitter of CO_2 if it were a nation (ahead of Brazil and Germany) (Balcombe et al., 2019). For the maritime industry to become decarbonized, time is running out. Consequently, countries decided on "indicative checkpoints" to decrease the total annual GHG emissions from international shipping by at least 20%, with a target of 30% by 2030, and by at least 70%, with a target of 80% by 2040, in comparison to 2008 (Saul, 2023). In the face of these developments, more environmentally friendly alternative fuels stand out as the fastest and most reasonable solution. However, companies have different preferences in this regard.

International official meetings on reducing carbon emissions and decarbonization are held on many different platforms. However, the date that stands out as an important meeting with the decarbonization agenda in the post-pandemic period was the United Nations Climate Change Conference of the Parties (COP26), which was held in Glasgow, Scotland from October 31 to November 12, 2021. This meeting was of great importance for global climate change negotiations and determination of climate policies. Decarbonization was also discussed as an important agenda item at this meeting. COP26 provided a platform for participating countries to update their climate targets and present more comprehensive decarbonization plans. Countries committed to move towards decarbonization through steps such as setting net zero emission targets and reducing fossil fuel-based energy production (BBC News, 2021). Until a consensus is reached in the industry, leading companies from different sub-sectors in the industry are trying to provide what is expected with different solutions.

Accordingly, it is aimed to evaluate the fuel strategies adopted by companies in line with the decarbonization journey. Therefore, COP26, which is an important official meeting with the decarbonization agenda in the post-pandemic period, was taken as a reference point in this study, and the news on what kind of steps companies took regarding alternative fuels in the maritime industry within the scope of decarbonization between November 2021 and June 2023 were scanned in the Thomson Reuters Refinitiv terminal. It is mainly aimed to determine what kind of strategies the industry participants have adopted for alternative fuels without making comparisons using technical terminology as much as possible. The scanning consisted of two stages. In the first stage, 130 news were listed as a result of filtering for company investments in alternative fuels. In the second stage, the filtered news were analyzed in detail and the news on company investments in Ammonia, Methanol, Hydrogen and LNG were included in the second section. Within the scope of combating climate change, there are various initiatives in the maritime industry as in other industries. Among the technologies developed, propulsion systems that enable the use of various alternative fuels such as Liquefied Natural Gas, Hydrogen, Ammonia, Marine Biofuels as well as synthetic fuels with reduced sulfur content other than the traditionally used Fuel Oil and Diesel Oil are being developed. Within the scope of combating climate change, these alternative fuels stand out due to their low emission values compared to conventional fuels and are frequently discussed in the existing literature (e.g. Al-Enazi et al. 2021; Balcombe et al. 2019). From the practitioners' point of view, it is seen that R&D studies are mainly focused on these fuels, and as emphasized in this study, large-scale investment projects for such alternative fuels stand out. If there is an official and original document shared as an attachment by the relevant company in the filtered news, the information contained in this document has been taken into consideration. The filtered news were also searched on the relevant company's own website. The news shared by some third-party news agencies (e.g. MarketLine), which are among the data providers of the terminal, were re-searched on google and the news in public and reliable news bulletins were taken into consideration. Since accessing the news from such agencies is paid, this approach was adopted in order to be able to cite the news and make them accessible to the readers of this study.

2. INTERIM STEPS TOWARD A SUSTAINABLE FUTURE IN SHIPPING INDUSTRY

Decarbonization requires substantial investments in green technologies and alternative energies. However, shipping companies are still waiting for "real green" fuel alternatives as part of the industry-wide push toward decarbonization. While many other fuels, such as methanol, hydrogen, and ammonia, and electric-powered ships are being explored, more and more ships are already switching to LNG (liquefied natural gas). Industry giants like Hapag-Lloyd are depending on technology to fill the gap until these new fuels are accessible. The corporation intends to become CO_2-neutral as early as 2045 and has purchased twelve new ships that will be propelled by LNG. The company issuing the green bond has received support from Deutsche Bank. Hapag-Lloyd may cut its short-term CO_2 emissions by up to 20% with just twelve ships. Even for a prosperous shipping firm, the investment expenditures of two billion euros are not insignificant, but the ships might gradually be upgraded to CO_2-neutral propulsion technologies (Deutsche Bank, 2022). States are involved in this as well as financial institutions. For example, Japan's minister of industry, Yasutoshi Nishimura, stated at a ministerial meeting of the Asia Zero Emission Community (AZEC) that Japan's government has committed to supporting ASEAN countries financially and technologically to help them accelerate their efforts to address climate change and decarbonize their economies. In an effort to reduce its reliance on filthy, conventional fossil fuels like coal and oil, Japan aims to become the world's leading hydrogen economy (Obayashi and Golubkova, 2023).

The world needs intelligent solutions to address the present climate concerns. The maritime industry is experimenting with several fuels to cut carbon emissions and satisfy standards established by the International Maritime Organization.

2.1. Methanol

When compared to typical marine oil, methanol as fuel can reduce emissions of SO_X, particulate matter (PM), NO_X, and CO_2 by up to 80% and about 15%, respectively (MOL, 2023b). However, methanol requires cargo tanks that are 2.5 times bigger than the ones they now have since it operates more efficiently than marine gasoil (MGO). Methanol has a low flash point, is poisonous, and is flammable. Additionally, methanol vapor dispersion and cloud behavior must be considered, and additional safety

measures must be adopted. Last but not least, green methanol is still not widely accessible at the level needed by the industry (Bureau Veritas, 2023).

It was observed that leading market players in Europe and Asia have been very aggressive in investing in methanol propulsion vessels. Maersk has purchased 19 ships that are capable of handling methanol on the European side in order to meet its goal of delivering 25% of all maritime transport with green fuels by 2030. The Danish shipping company aims to have zero net greenhouse gas emissions by 2040 (Birkebaek, 2023). Greek shipowner Danaos Corporation, which has a fleet of 77 containerships, has ordered four containerships with a capacity of 7,200 twenty-foot equivalent unit (TEU) (Danaos Corporation, 2022).

Speaking of container lines, a collaboration agreement between China State Shipbuilding Corporation and France's CMA CGM Group would result in the construction of 16 massive container ships worth over 21 billion yuan (about 3 billion U.S. dollars). It establishes a new record for the largest single order ever placed for the construction of container ships in China. It consists of 12 container ships with a capacity of 15,000 TEU that run primarily on methanol (Zishuo, 2023).

It was observed that RoRo companies are also active in some respect. For instance, two hybrid cargo ships have been designed and ordered by Stena RoRo on behalf of Stena Line from the Chinese shipyard CMI Jinling in Weihai. The ships have been designed to meet future environmental criteria, such as employing batteries as a future form of propulsion and can run on methanol or conventional fuel (Stena RoRo, 2023).

Moreover, there have been concrete steps that European small tonnage shipowners, especially those responsible for large fleet management, are not lagging behind in this regard. For instance, one of the top shipping corporations in Europe, Vertom, is collaborating with Thecla Bodewes shipyards in the Netherlands on a proposal to construct a series of six LABRAX vessels, each measuring 7,000 DWT and powered by diesel and electricity and design which is able to convert methanol fuel or hydrogen power to adapt current decarbonization efforts (Vertom, 2022).

Also, players in tanker market seem to be active. For example, the first methanol-powered new build ship from Chinese builders Guangzhou Shipyard International (GSI) has been delivered to Proman Stena Bulk.

Methanol manufacturer Proman and tanker shipping operator Stena Bulk have partnered to become Proman Stena Bulk. Six methanol-powered new build vessels are being built by GSI for Proman Stena Bulk and Proman. The new Stena Pro Patria, a 49,990 dwt IMO-II MeMAX dual-fuel mid-range (MR) tanker, is now getting ready for commercial service (Stena Bulk, 2023).

On the Asian side, the news that the leading players in the container market have joined the bandwagon has been widely shared recently. For instance, Ocean Network Express (ONE) has awarded contracts to Hyundai Heavy Industries and Nihon Shipyard for the building of ten very large container ships (VLCS). According to the agreements, Nihon and Hyundai would each build five VLCS with a nominal capacity of more than 13,700 TEUs. Delivery of the ships is expected for 2025 (ONE, 2022). Moreover, the third methanol-fueled chemical tanker, Grouse Sun, has been delivered to Japanese shipping firm Nippon Yusen Kabushiki Kaisa (NYK) Line. Grouse Sun has a dual-fuel engine that can run on both heavy fuel oil and methanol. Additionally, the ship includes revolutionary technology that reduces NO_X emissions when utilizing methanol as fuel by adding water to the fuel to lower its temperature during combustion. As a result, the ship doesn't require an exhaust gas recirculation system (EGR) or a selective catalytic reduction (SCR) device in order to meet the demanding Tier III NO_X emission standard set by the IMO and help promote environmentally friendly transportation (NYK Group, 2022b).

A brand-new dual-fuel methanol carrier has been delivered to Mitsui OSK Lines (MOL) at Hyundai Mipo Dockyard in South Korea. The ship, Cypress Sun, has been built to run on both methanol and conventional heavy fuel (MOL, 2023a). The largest container shipper in South Korea, HMM Co., agreed to a 1.41 trillion won (US$1.1 billion) contract with two regional shipbuilders to build nine methanol-powered container ships as part of their attempt to become carbon neutral. (Yonhap News Agency, 2023).

There are similar developments in special purpose vessels. For instance, a Multi-Carrying Vessel of P&O Logistics will soon be transformed into a Cable-Laying Vessel. To assist it achieve the goals, the company's recently redesigned vessel will be equipped with a state-of-the-art battery system and a low fuel consumption engine architecture for environmentally friendly methanol fuel (P&O, 2023).

2.2. LNG

Typically, LNG is viewed as a viable marine fuel that will assist the industry in achieving its objective of a 50% reduction in GHG emissions by 2050. Meantime, LNG serves as a fuel that helps shipping achieve its decarbonization targets in anticipation of hydrogen and ammonia becoming economically feasible. LNG as a marine fuel typically results in 97% lower SO_X, 97% lower particulate matter, 85% lower NO_X, and up to 20 percent lower overall GHG emissions than ships powered by standard fuel oil. Looking at the latest developments, Hafnia participated in the decarbonization process with a different choice with the addition of four LR2 type tankers with new built LNG propulsion system to its fleet (Hafnia, 2022).

A dual-fuel, liquefied natural gas (LNG) VLCC, "Yuan Rui Yang", was built by Dalian Shipbuilding Industry Company (DSIC) in China and delivered to shipping company COSCO Shipping (MarineLink, 2022). As a temporary solution before the development of future emission-free ships, Japanese shipping company Nippon Yusen Kabushiki Kaisha (NYK) Group is placing LNG fuel. The company placed orders for the first large coal carrier powered by LNG in the world in 2019, its first capesize bulk carrier powered by LNG in 2021, four other LNG-powered capesize bulk carriers in January 2022 and two LNG-fueled coal carriers in November 2022 (NYK Group, 2022c). Plumeria Leader, a pure car and truck carrier (PCTC) that can travel across oceans using just LNG as the ship's primary fuel, was delivered to NYK (NYK Group, 2022a).

NYK, MTI Co., Ltd., and Elomatic Oy have completed the concept design phase of a new capesize bulk carrier and a very large crude oil tanker (VLCC) as part of a project to construct an LNG-fueled vessel that can be successfully converted to an ammonia-fueled vessel, or ARLFV, an ammonia-fuel ready LNG-fueled vessel. The three companies are pitching ARLFVs as the next step in the development of emission-free ships. They will work with shipyards and suppliers of marine equipment to move forward with designing a genuine ARLFV in the future. However, the main challenge in designing and developing ARLFVs is the need for greater fuel tank capacity to keep endurance at the same level due to the lower energy density of ammonia compared to LNG. This affects the space for cargo loading, ship stability and hull strength depending on the need for a larger fuel tank (NYK Group, 2022d).

2.3. Hydrogen with Marine Fuel Cells

The development of hydrogen technology is essential to enabling the widespread use of renewable energy sources like wind and solar energy. Countries and companies have embraced green hydrogen as a strategy to reduce GHG emissions, particularly from heavy industry. Green hydrogen is a fuel created by channeling renewable electricity through water to split the element from oxygen. However, the use of hydrogen still faces numerous difficulties, much as offshore wind did twenty years ago. It still costs a lot to produce, requires a lot of clean drinking water, which is becoming increasingly limited in many areas, and transportation is still difficult (Port of Rotterdam, 2023b).

Fuel cells offer a reliable method of creating low-carbon electricity (Staffell et al. 2019), but additional infrastructure and system design are required due to the low volumetric energy density and widespread availability of hydrogen. The supply chain for hydrogen has emissions as well, which must be taken into account even though hydrogen fuel cells do not directly produce greenhouse gases. Only a small number of hydrogen fuel cell ships are in operation. The "Viking Lady" was the first commercial ship to use fuel cell technology for supplemental propulsion. An LNG-powered diesel engine provided the ship's primary propulsion, and a fuel cell that ran on methanol or hydrogen provided backup (with reconfiguration). This technology completely eliminated SO_X, reduced NO_X by 85%, and reduced CO_2 by 20% (Balcombe et al., 2019).

An international order has been placed with Cochin Shipyard Limited (CSL) for the first emission-free feeder container vessel ever. In the end, green hydrogen will be used to power the ship's hydrogen fuel cells. The order for the design and construction of two zero emission feeder container vessels, with an option for two further vessels, has been obtained from M/s. Samskip Group, a worldwide logistics solution provider. These ships, which can accommodate 365 high-cube containers each measuring 45 feet long, are designed to service the European market, which has a high demand for environmentally friendly shipping options. Each vessel is anticipated to reduce CO_2 emissions by about 25,000 tons annually while operating in zero-emission mode. By utilizing green shore power at the ports, they will also accomplish zero emission operations (ANI News, 2023).

On April 20, 2023, the Port of Rotterdam, Europe's largest seaport and HGK Shipping, the largest inland waterway shipping firm in Europe inked a long-term partnership agreement to develop sustainable concepts for inland waterway services leading to and from seaports. The article largely focuses on the energy revolution, hydrogen logistics, and lowering CO_2 emissions through the employment of novel motor concepts and digitalization (Port of Rotterdam, 2023a).

2.4. Ammonia

Since ammonia does not produce CO_2 when it is burned, it has become more popular as a fuel that has the potential to dramatically lower greenhouse gas (GHG) emissions in the maritime industry (Inpex Corporation, 2023). However, due to safety issues and associated costs, industry players have expressed doubts about the viability of using ammonia as a bunkering solution.

With a main engine from MAN and a bridge system from Kongsberg, the Aurora Class ships of Hoegh Autoliners to transport up to 9,100 cars, will be a remarkable development in the PCTC segment to acquire ammonia and methanol ready notations of DNV. 1500 square meters of solar panels were incorporated into the vessel's design. Additionally, while in port, the Aurora will be prepared to accept electric shore power for zero emission operations (Höegh Autoliners, 2022).

In the same segment, the Grimaldi Group placed an order for five additional Ammonia-Ready Pure Car & Truck Carriers (PCTC), bringing the total expenditure to more than USD 630 million. The RINA Ammonia Ready class marking will be applied to the new ships, indicating that they may be converted to run on ammonia as a substitute, carbon-free fuel. Additionally, they will be built to allow for cold ironing using shoreside energy supplies, which is a greener option to burning fossil fuels while in port. Thanks to innovations in design and state-of-the-art engines and systems, their CO_2 emissions per cargo unit transported index will be 27% lower than that of earlier generations of ships (Grimaldi, 2023a), and in May 2023, the option for two another sister ships was eventually exercised (Grimaldi, 2023b). It has been observed that ammonia propulsion systems are also preferred in LNG carriers. An ocean-going liquefied gas carrier was built in partnership by Mitsui OSK Lines, Tsuneishi Shipbuilding, and Mitsui E&S Shipbuilding. Ammonia will be used as the primary fuel for the vessel being built under the joint project (Shen, 2022).

3. IN UNITY, THERE IS STRENGTH

There is no doubt that whatever alternative fuel is needed, it becomes very important that the supply chain of the fuel in question is robust. Finding a consistent supply of cleaner fuels is one of the firms' major issues as they move away from diesel, which has led the corporations to find alternative solutions. It is also essential that the manufacturers of the technological products needed are integrated into the system. It has also been observed that there are collaborations between shipping companies investing in this field and stakeholders such as system designers, machinery manufacturers and various suppliers.

To hasten the production of eco-friendly marine fuels, Maersk has agreed to a strategic partnership with US-based project creator Carbon Sink. Carbon Sink will construct eco-friendly methanol production facilities in the US in accordance with the letter of intent (LOI) arrangement made in this regard. Maersk intends to purchase the total volume from the project and has options for the output from further Carbon Sink facilities that will be built at different locations (Ajdin, 2022). Maersk is presently collaborating with eight strategic partners, including Carbon Sink, to deliver green fuel for the 19 methanol-powered boxships it has ordered thus far. In this regard, Maersk and the Spanish government worked together earlier this month to research the nation's large-scale manufacturing of green fuels. According to estimates from the Spanish government, the project will require an investment of around 10 billion euros ($9.75 billion), and Spain may participate as a strategic investor (Reuters, 2022c). A memorandum of agreement for a green methanol marine fuel project in the Shanghai port has been signed by Maersk and Shanghai International Port Group. Such collaborations to address the supply concerns of the Maersk group, which is preparing for a major overhaul of its fleet, is also expected to have a very strategic impact for the other parties to the agreement. Accordingly, the owner of the busiest container port in the world, Shanghai International Port Group, expects to establish itself as a major regional hub for the bunkering of green methanol fuel (Maersk, 2023).

Maersk also cooperates with engine manufacturers as part of its strategies to achieve its goals. For instance, six methanol engines will be delivered to MAN Energy Solutions by Hyundai's shipbuilding division (HHI-SBD) and placed on container ships made for Maersk. According to the agreement, the company will provide six 17,000 TEU container ships

with MAN dual-fuel main engines. Green methanol is intended to power the engines (MAN Energy Solutions, 2022). Winterthur Gas & Diesel (WinGD) will supply methanol engines for boxships owned by Cosco Shipping Lines. Four 16,000 TEU container ships that will be constructed at Cosco Shipping Heavy Industry (Yangzhou) will receive the methanol-fueled from the company (WinGD, 2023).

CMA CGM joins the Grtgaz-led Jupiter 1000 Project, France's first industrial demonstration of the production of hydrogen and e-methane. Creating hydrogen and e-methane from renewable energy to support the creation of low-carbon solutions hoping to hasten the pace of its fleet's switch to new, extremely low-carbon fuel sources by taking part in the project (CMA CGM, 2022). In an effort to create the sustainable marine fuel, CMA CGM and energy company Engie intend to begin producing biomethane in France in 2026. The French companies intend to construct a facility near the port of Le Havre that will use wood waste to annually produce 11,000 tons of biomethane (Reuters, 2022b).

Ammonia agreements are also available. For example, Yara of Norway and Azane Fuel Solutions have partnered to build a network of bunker ports across Scandinavia so that ships may receive marine fuel that has no carbon (Reuters, 2022a). In addition, a project to construct a cargo ship that runs on green ammonia will be collaborated on by Green NortH2 Energy Oy, Wartsila Corp, and Meriaura Oy, a Finnish marine logistics firm. The vessel, which will have modular multifuel main engines provided by Wartsila, will be ordered and operated by Meriaura in accordance with the conditions of a recently signed contract of intent. On the other hand, green ammonia fuel will be provided by Green NortH2 Energy (Shumkov, 2022).

4. DISCUSSION AND CONCLUSION

It is aimed to provide insights into the evolving landscape of fleet modernization strategies for alternative fuels in the shipping industry, which in the global effort to combat climate change. As the urgency to reduce GHG emissions, shipping companies are actively exploring various approaches to decarbonize their operations. However, due to the wide variety of sizes and types of ships in the shipping industry, it is challenging to come to an agreement on decarbonization laws and policies. A corporation in one nation may own ships, yet the owner may be a foreign national. They could also be run by a business in another nation and

registered in a different nation (that nation's flag country) (Dong et al. 2022). Yet, there is a definite trend toward eco-friendly alternative fuels, which reflects a shared commitment to sustainability. It has been determined within the scope of this study that companies in the liner shipping, especially container lines, have serious investments in this context. The strategies used by the companies, whether through the retrofitting of current ships or the investment in new ships specialized for certain alternative fuels, are illustrative of a dynamic industry aiming to comply with global decarbonization goals.

Current developments show that emission regulations will lead to significant technological changes in the industry. Although there are different alternatives, each has different barriers to general acceptance in terms of cost and resources. Decarbonization of the industry requires addressing a multitude of issues and developing a multifaceted and inclusive policy from all sub-components of the industry, as it is clear that there is no single right way (Mallouppas and Yfantis, 2021). It is critical that there be consistent guidelines for all market participants in addition to the development of alternative fuels and engines. The solution lies in using alternative fuels whose combustion emits little to no greenhouse gases because massive ships cannot be run electrically like vehicles, and even slower sailing or better ship operations will not result in the necessary CO_2 savings. However, availability of cleaner fuels continues to be an issue, also lacking is the infrastructure for loading and fueling ships along the commerce routes (Deutsche Bank, 2022). Engine and ship designers are required to provide fully green solutions, according to a speech made by Haralambos Fafalios, chairman of the Greek Shipping Co-operation Committee (GSCC), at an annual conference in London at the start of 2023. It was also emphasized that, until safe alternative fuels are widely available in the long run, a simple inducement like a fuel charge as a medium-term strategy is needed. In an effort to find new alternatives to dirtier bunker fuel, the industry has been exploring a number of cleaner fuel sources (Reuters, 2023). Also, an increasing collection of material that examines the possibility of cleaner alternative fuels for the maritime transportation industry is available, such as modern methods and technologies (e.g. Bouman et al. 2017), and cleaner alternative fuels (e.g. Al-Enazi et al. 2021), but the research is still scarce.

Considering the analyzed news, ships with methanol and LNG propulsion systems are prioritized more by companies within the scope of the decarbonization efforts of the industry. In fact, by 2050, methanol and LNG are predicted to occupy the largest market shares for alternative

bunker fuels in Fujairah, based on the outcomes of an online poll conducted during the FUJCON forum (Lerh, 2023). Although developments in biofuels have also been identified, it has been observed that they are still in their infancy and research and development phases are still ongoing. Nevertheless, it should be emphasized that some of the leading container lines have made serious moves in this area.

An important issue related to this topic is that decarbonization process of the industry provides significant opportunities for the national economies. For instance, new building investments spurred by emission regulations certainly generate a significant economic impact for countries especially with a large share of the world's shipbuilding activities. South Korea, with its highly developed technological competitiveness in the face of high value-added, environmentally friendly shipbuilding orders, has boosted its global market share to 37%. Korea's market share increased by 4% to 37% in 2022 due to the 22% drop in global orders over the previous year. In terms of fuel type, over 92% of Korea's orders are for LNG-fueled carriers, which are followed by methanol- and LPG-fueled carriers, respectively, at 5% and 3%. Specifically, Korean shipbuilders accounted for the majority (54%) of worldwide orders for LNG-fueled carriers, leading the market share (MOTIE, 2023). From this perspective, it also offers an important window of opportunity for the Turkish shipbuilding industry. In addition, developing policies that provide added value from all logistics processes, especially transportation and storage systems related to supply of cleaner fuels mentioned, will make a significant contribution to the national economies.

Last but not least, there is a huge financial challenge associated with decarbonizing the industry. Many shipping companies struggle to secure the necessary funding for these initiatives since swapping to cleaner fuels or technologies frequently necessitates sizable upfront costs. Furthermore, uncertain investment returns, restricted access to affordable capital, a lack of sufficient investment incentives, high development costs for infrastructure, technology-related risks, volatile market and fuel prices, competitive pressures, and a lack of uniform regulations could be other challenges that could be taken into consideration in future studies. In order to make sustainable practices financially viable and desirable for the shipping industry, it will be necessary to address these complex issues and develop supportive governmental frameworks, industry-wide collaboration, and new finance options.

ACKNOWLEDGMENT

I am using this opportunity to express my gratitude to Prof. Dr. M. Banu Durukan Salı for her valuable comments to the development of this study.

Conflict of Interest

There is no conflict of interest between the authors in the study.

Financial support

No support was received from any institution for this study.

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