www.ijarp.com ISSN 2456-9992 Page: 01-31

International Journal Advanced Research Publications

Research Article

Volume: 01

Issue: 03

EFFECT OF GREEN SHIPPING PRACTICES ON PORT DIGITALIZATION IN NIGERIA

[*1]Charles, Adokiye Precious, [2]Orji, Charles Ugochukwu

1Department of Maritime Science, Faculty of Science, Rivers State University, Nkpolu Oroworukwo, Port Harcourt, Nigeria.

2Centre of Excellence in Marine and Offshore Engineering, Faculty of Engineering, Rivers State University, Nkpolu Oroworukwo, Port Harcourt, Nigeria.

Article Received: 22 October 2025, Article Revised: 13 November 2025, Published on: 03 December 2025

***Corresponding Author: Charles, Adokiye Precious**

Department of Maritime Science, Faculty of Science, Rivers State University, Nkpolu Oroworukwo, Port Harcourt, Nigeria. DOI: https://doi-doi.org/101555/ijrpa.2088

ABSTRACT

The study examined the effect of green shipping practices on port digitalization in Nigeria. The dependent variable focused on port digitalization (PORDIG) which served as the regressand or measure. The dimensions or the predictor variables of green shipping practices analyzed included energy-efficient vessels (ENEGEV), decarbonization of maritime transport (DEMATR), and technological innovation (TECHIN) and they served as the regressors. The data utilized for the study were time series data sourced from the Nigerian Ports Authority (NPA), Nigerian Maritime Administration and Safety Agency (NIMASA), Nigerian Shippers' Council (NSC), Nigerian Navy and Marine Police (NNMP), National Inland Waterways Authority (NIWA) and Federal Ministry of Marine and Blue Economy (FMMBE) between the period of 1990 to 2024. The analytical techniques employed were Phillip-Perron unit root test and bounds cointegration test. The model was estimated using Autoregressive Distributed Lag (ARDL) model. The unit root test revealed that the variables have mixed order of integration I(0) and I(1). This led to the application of ARDL bounds test to confirm cointegration. The result indicated the presence of a long run relationship amongst the dependent and independent variables examined in the model. The result revealed that energy-efficient vessel has significant positive effect on port digitalization in the short run. Also, decarbonization of maritime transport and technological innovation have significant positive effects on port digitalization in both the short run and long run. Thus, the study recommends among other things, that government should encourage the acquisition of energy-efficient vessels and decarbonization of maritime transport system to align with technological innovations development of the maritime sector. Also, regulatory frameworks should prioritize carbon reduction strategies, including stricter emission controls and incentives for low-carbon shipping practices.

KEYWORDS: Green Shipping Practices, Energy-Efficient Vessels, Decarbonization of Maritime Transport, Technological Innovation, Port Digitalization

INTRODUCTION

Nigeria, endowed with vast maritime resources and a strategic coastal location, holds immense potential for port digitalization and ecological conservation. However, the nation's marine and coastal ecosystems are under increasing threat from unsustainable shipping practices, environmental degradation, and insufficient adoption of modern green technologies (Odiegwu & Zeb-Obipi, 2023).

Green shipping practices—such as the deployment of energy-efficient vessels, the decarbonization of marine transport, and the integration of technological innovations—have emerged globally as pivotal strategies for reducing the environmental footprint of maritime activities. Despite international trends, Nigeria's maritime sector still lags in fully embracing these practices. The lack of energy-efficient vessels, limited policy frameworks supporting decarbonization, and slow pace of port digitalization continue to hamper both port digitalization and economic optimization (Nwogu, 2022).

Port digitalization is one of four key categories of port innovation. These innovations consist of robotics, process automation, decision-making automation, and digitalization (Zhang et al., 2024). These four innovations lead to a more efficient supply chain management. Specifically, digitalization is changing the way ports operate, turning them into smart port, creating Digital Twins, and thus affecting the entire maritime and logistic supply chains (Ali, 2023)

The transition to green shipping also intersects with broader global challenges, such as climate change adaptation and social equity. Rising sea levels and extreme weather events pose risks to maritime infrastructure and operations, necessitating resilient designs and contingency planning (Gangani et al, 2024). Francois et al, (2024) explored the integration of climate risk assessments into maritime decision-making processes, highlighting the need for proactive measures to safeguard the industry's future. Social equity considerations, such as the impact of decarbonization on seafarers and coastal communities, are also critical. Researchers have emphasized the importance of inclusive policies that ensure a just transition, balancing environmental goals with the needs of vulnerable populations.

While some efforts have been made to promote port digitalization in the maritime sector, there is limited empirical research examining how the adoption of green shipping practices directly influences the development of port digitalization in Nigeria. Furthermore, there is inadequate data on the extent to which technological innovations and decarbonization strategies contribute to ecological and economic transformation in the maritime domain (Mohammud & Radu, 2023). This gap presents a significant challenge to the realization of a port digitalization in Nigeria. Port digitalization remains underdeveloped due to pollution and degraded ecosystems.

Researchers have explored strategies to reduce emissions at ports, such as the use of shore power systems that allow ships to turn off their engines while docked. Electrification of port equipment and the adoption of renewable energy sources for port operations are additional measures being implemented. Ports are also being reimagined as energy hubs, capable of supporting alternative fuel bunkering and serving as nodes for renewable energy distribution. Collaborative efforts between port authorities, shipping companies, and governments are essential to realize these visions, and researchers have emphasized the importance of integrated planning and investment (Song, 2024). The study analyzed the effect of green shipping practices (represented by technological innovations, energy-efficient vessels, and decarbonization of marine transport) on port digitalization in Nigeria.

Objectives of the Study

The following specific objectives were addressed in the study:

1. To evaluate the effect of energy-efficient vessels on port digitalization.
2. To determine the effect of decarbonization of marine transport on port digitalization.
3. To determine the effect of technological innovations on port digitalization

Research Questions

The following research questions were raised based on the objectives of the study:

1. To what extent do energy-efficient vessels affect port digitalization?

2. To what extent does decarbonization of marine transport affect port digitalization?
3. To what extent do technological innovations affect port digitalization?

Research Hypotheses

The following research hypotheses were tested in the study:

Ho_1: Energy-efficient vessels have no significant effect on port digitalization.

Ho_2: Decarbonization of marine transport has no significant effect on port digitalization.

Ho_3: Technological innovations have no significant effect on port digitalization.

LITERATURE REVIEW

Theoretical Framework

Green shipping theories explore how to minimize the environmental impact of shipping while balancing economic and operational realities. They encompass a range of approaches. In this section, theories such as theory of change and green theory, have been used in this study.

Theory of Change

The origin of the theory of change can be found in the considerable body of theoretical and applied development in the evaluation field, especially among the work of people such as Huey Chen, Peter Rossi, Michael Quinn Patton, and Carol Weiss (Weiss,1995; James, 2011). These evaluation theorists and practitioners, along with a host of others, have been focused on how to apply program theories to evaluation for many decades. A theory of change (ToC) is a framework that outlines how and why an initiative is expected to lead to specific outcomes and impacts. It maps out the causal pathways between activities and desired results, explaining the logic behind the program's design. ToCs are used in program development, design, and evaluation, helping to identify assumptions, risks, and potential areas for improvement (James, 2011).

A theory of change is a method that explains how a given intervention, or set of interventions, are expected to lead to a specific development change, drawing on a causal analysis based on available evidence. In the UNDAF context, a thorough theory of change helps guide the development of sound and evidence-based programme strategies, with assumptions and risks clearly analysed and spelled out (Taplin et al., 2013).

Theory of Change is essentially a comprehensive description and illustration of how and why a desired change is expected to happen in a particular context. It is focused in particular on mapping out or "filling in" what has been described as the "missing middle" between what a program or change initiative does (its activities or interventions) and how these lead to desired goals being achieved. It does this by first identifying the desired long-term goals and then works back from these to identify all the conditions (outcomes) that must be in place (and how these related to one another causally) for the goals to occur (Varriale et al., 2021). These are all mapped out in an Outcomes Framework. The Outcomes Framework then provides the basis for identifying what type of activity or intervention will lead to the outcomes identified as preconditions for achieving the long-term goal. Through this approach, the precise link between activities and the achievement of the long-term goals are more fully understood. This leads to better planning, in that activities are linked to a detailed understanding of how change actually happens. It also leads to better evaluation, as it is possible to measure progress towards the achievement of longer-term goals that goes beyond the identification of program outputs (James, 2011).

Green Theory

Green Theory is a profound and evolving approach within literary and cultural studies that focuses on the relationship between humans and the environment (Wake & Malpas, 2013). Also known as ecocriticism, Green Theory examines how nature is portrayed in literature and the role of literature in advocating environmental protection. It encompasses physical phenomena such as plants, animals, and landscapes and a powerful force often called "Nature" (Marland, 2013). Within Green Theory, culture is viewed as human activity concerning nature, including inhabitation, cultivation, business, and worship, and human culture is seen as part of the broader natural culture. The pastoral tradition in literature, celebrated for its idealized portrayal of rural life and nature, is critiqued within Green Theory for mystifying rural production relations (Coupe, 2013). At the same time, Kenneth Burke stressed the need to integrate ecological awareness with literary criticism, viewing human language as rooted in biological processes and nature (Nwokolo & Ahia, 2023).

Green Theory is instrumental in promoting environmental justice and sustainability, making it a cornerstone in literary and maritime studies. It offers profound insights into the complex relationships between humans and the natural world. It continues to evolve in addressing global issues, providing hope for a more balanced and harmonious future (Chang & Danao, 2017). Through the works of influential scholars and critical strands like ecofeminism, Green Theory challenges traditional notions and invites us to reconsider our relationship with nature, firmly establishing itself as a vital framework for shaping a more sustainable future for all, hence its application as a very anchor theory for the effect of green shipping practices on blue economy development (Chang & Danao, 2017).

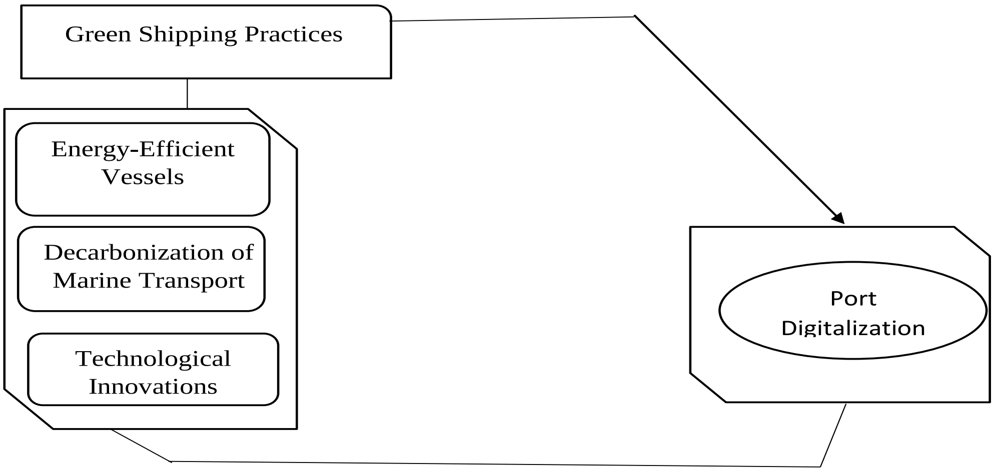

Figure 1: Conceptual Framework of the Effect of Green Shipping Practices on Port Digitalization in Nigeria

Sources: Elegbede et al.(2023a); Enyioko and Amadi (2025); Odiegwu and Zeb-Obipi (2023); Mi et al. (2024), Karagkouni and Boile (2024), UNCTAD (2024), Ajayi (2024), Rok et al. (2024) and Empirical Literature Survey, 2025.

Conceptual Review

Green Shipping Practices

Green shipping practices involve a range of strategies to minimize the environmental impact of shipping, including using alternative fuels, reducing emissions through operational efficiencies, optimizing routes, and minimizing waste through sustainable packaging and recycling. These practices aim to improve energy efficiency, reduce pollution, and protect marine ecosystems (Mi et al., 2024). The maritime industry has long been a cornerstone of global trade and economic activity, but its environmental footprint, particularly its greenhouse gas emissions, has increasingly come under scrutiny (Mikalai et al, 2024). The concept of "green shipping" has emerged as a response to growing environmental concerns, with researchers and industry stakeholders focusing on practices and technologies that mitigate the sector's impact on the environment.

Green shipping has taken center stage of many environmental discussions. Osuji and Agbakwru (2024) noted that green shipping involves the implementation of the principles of sustainable development in the shipping sector. It defines how shipping firms go about their environmental responsibility in the course of rendering their shipping services (Poi & Moko, 2023).

Port operations and their role in green shipping have been extensively studied as well. Shore power systems, also known as cold ironing, have been identified as a critical strategy for reducing emissions from ships while at berth (Glavinovic et al, 2023). These systems allow ships to connect to the local electrical grid, eliminating the need to run auxiliary engines for power. Case studies from ports in Europe and North America have demonstrated significant reductions in air pollutants and greenhouse gas emissions. The integration of renewable energy sources into port operations, such as wind and solar, has further enhanced the environmental performance of these systems.

Green shipping has emerged as a critical area of focus within the maritime industry, driven by the need to reduce environmental impacts, enhance energy efficiency, and address growing concerns over climate change (Kee-Hung et al, 2011). Several studies have investigated various aspects of green shipping, exploring its potential to contribute to a sustainable maritime sector. This conceptual review examines the relevant literature on topics closely related to green shipping practices, technologies, and strategies, with a particular emphasis on research that informs the objectives outlined.

The concept of green shipping has been widely explored through investigations into innovative practices and technological advancements aimed at minimizing the environmental footprint of maritime transportation (Mi et al, 2024). A significant body of research has delved into alternative fuel options, such as liquefied natural gas (LNG), hydrogen, ammonia, and biofuels, as viable substitutes for traditional fossil fuels.

Energy-Efficient Vessels

The concept of energy-efficient vessels involves minimizing energy consumption and emissions while maintaining or improving ship performance. This includes reducing fuel consumption, improving fuel efficiency, and lowering greenhouse gas emissions. It's achieved through a combination of design improvements, operational practices, and technological advancements (Hassan et al., 2023).

Energy-efficient vessels prioritize minimizing energy consumption and emissions while maximizing operational efficiency. This involves incorporating technologies and practices that reduce fuel consumption, lower greenhouse gas emissions, and improve overall operational performance. Key aspects include optimizing hull design, utilizing efficient propulsion systems, implementing advanced energy management strategies, and promoting operational practices that minimize energy waste (IMO, 2024).

Energy efficiency indicators for sea-going ships intended for international voyages are used for a decade and are provided by the International Maritime Organization (IMO). They can be divided into design and operational ones. Firstly, a design indicator labelled as energy efficiency design index (EEDI) became mandatory for new ships over 400 GT built between 2013 and 2015, under the MARPOL Annex VI. EEDI criterion has been strengthened over the years, namely in 2015, 2020, and expected to be strengthened in 2025. In 2023, existing ships faced the IMO’s regulatory examination through the compulsory requirements of the energy efficiency existing ship index (EEXI) (El-Omda et al., 2025).

Decarbonization of Marine Transport

Maritime decarbonization is the process of reducing greenhouse gas (GHG) emissions from the global maritime sector, with an overall goal of placing the sector on a pathway that limits global temperature rise to 1.5-degrees Celsius. The tool can analyze the costs and emissions reduction impacts for three main carbon reduction strategies: electrification, RNG, and green hydrogen (Akujor et al., 2022).

Decarbonizing marine transport involves transitioning the shipping industry to reduce its greenhouse gas emissions and move towards a net-zero future. This is a global effort driven by the International Maritime Organization (IMO), with the goal of achieving net-zero emissions by or around 2050. The transition involves several strategies, including using alternative fuels, improving vessel efficiency, and adopting new technologies (IMO, 2021).

Maritime decarbonization is the process of reducing greenhouse gas (GHG) emissions from the global maritime sector, with an overall goal of placing the sector on a pathway that limits global temperature rise to 1.5-degrees Celsius. The maritime industry is at the onset of a once-in-a century energy transition as it looks for ways to decarbonize rapidly through electrification and low-carbon fuels, optimization tools, and efficiency technologies (Luis et al., 2023).

Decarbonization strategies in the maritime industry have been extensively evaluated, with a focus on their effectiveness in reducing greenhouse gas emissions. The IMO's Initial Strategy on the Reduction of Greenhouse Gas Emissions from Ships, which aims to reduce emissions by at least 50% by 2050 compared to 2008 levels, has provided a framework for research in this area. Studies have analyzed various approaches, including operational measures, market-based mechanisms, and technological solutions (Serra & Fancello, 2020).

Technological Innovations

Technology innovation is defined as the creation and application of new or improved technologies, tools, systems, and processes that bring about significant advancements or breakthroughs in various fields (Olaniyi et al., 2024). It involves harnessing knowledge, expertise, and resources to develop innovative solutions that solve problems, improve efficiency, drive progress, and deliver value (El-Omda, et al., 2025).

Technological innovation refers to the implementation of new technologies or the significant improvement of existing technologies, resulting in advances in efficiency, productivity and competitiveness (Atedhor, 2023). This concept covers various activities, from the development of new products and processes, to the acquisition of more advanced management systems or the improvement of technological infrastructure (Barbu et al., 2022).

Through technological innovation, it becomes possible for businesses to adapt more quickly to market changes, meet public demands effectively and stand out in an increasingly competitive environment. In addition, technological innovation can reduce operating costs, increase the quality of products and services and open up new business opportunities, thus contributing to the creation of value and the longevity of companies (Bofan et al., 2024).

Technology innovation is a major driver of economic growth and competitiveness. It fosters the development of new industries, job creation, and increased productivity. Countries and organizations that prioritize technology innovation can gain a competitive advantage, attract investment, and stimulate economic development (Kolios, 2024). Technology innovation drives improvements in efficiency and productivity. By introducing new technologies, automation, and streamlined processes, organizations can optimize operations, reduce costs, and increase output. This leads to improved efficiency, higher profitability, and the ability to deliver products and services more effectively (Jakobsen et al., 2023).

Port Digitalization

Port digitalization is the process of integrating digital technologies to transform port operations, aiming to enhance efficiency, transparency, and competitiveness. It involves utilizing technologies like IoT, big data, AI, and blockchain to automate processes, improve decision-making, and create smart, interconnected port ecosystems. This transformation enables ports to become more efficient, sustainable, and responsive to the needs of various stakeholders within the global supply chain (Chang & Danao, 2017). Port digitalization is one of four key categories of port innovation. These innovations consist of robotics, process automation, decision-making automation, and digitalization (Zhang et al., 2024).

These four innovations lead to a more efficient supply chain management. Specifically, digitalization is changing the way ports operate, turning them into smart port, creating Digital Twins, and thus affecting the entire maritime and logistic supply chains (Yui-yip et al., 2024)

Port digitalization refers to the use of digital technologies to optimize port operations, enhance logistics, and improve overall efficiency in cargo handling, security, and sustainability. Digitalization allows ports to automate many traditional manual processes, reducing human error, and improving real-time data management (Zabel, 2023). It involves integrating technologies like IoT (Internet of Things), AI (Artificial Intelligence), blockchain, and big data analytics into port operations.

Port digitalization is the digital transformation of port processes. These processes are always collecting new data, evolving, and learning. This gives stakeholders real-time situational awareness of all events going on in their ecosystem. To fully digitalize operations, all stakeholders must be on board, as it influences the entire supply chain. Although digitalization improves efficiency and effectiveness, there must be an idea of collaboration not only between stakeholders but also between ports. This transformation is a big cultural change for the maritime industry, an industry born in the 15th century (Su, et al., 2024).

Port digitalization is the foundation of Smart Ports and Digital Twins. Digital Twins use technologies like Big Data, IoT sensors, Artificial Intelligence, and blockchain. Although these tools and solutions can transform real-time data into accurate and more precise business decisions, the most important aspect is that the digitalization and technology used is deliverable and configurable (Yui-yip et al., 2024).

Port digitalization is extremely effective for operations. Cranes and vehicles can be automated, saving time and money, real-time data can be shared, and essentially all stakeholders can know exactly what is going on during port operations. Ports can adopt automation processes, process cargo and containers at a higher speed with less error, and increase their effectiveness. Port digitalization, in the future, can go as far as to create an interconnectedness between all maritime actors. This is a long-term solution that would connect an international network of Smart Ports which would increase transparency between shipping companies, ports, and stakeholders (Nguyen et al., 2025).

Port digitalization is changing the container handling industry. With a growing world and economy, ships are getting larger, and more containers are being unloaded at terminal docks. Thanks to port digitalization, port quay operations are becoming safer, more efficient, more accurate, and more traceable. This fixes the past issue of terminals being unsafe due to heavy machinery, data inaccuracy, and untraceable activities (Karagkouni & Boile, 2024).

Effect of Energy-Efficient Vessels on Port Digitalization

Falcone (2023) examined sustainable energy policies in developing countries: A review of challenges and Opportunities. The study revealed that green shipping practices and port digitalization are intertwined and mutually reinforcing, leading to more sustainable and efficient port operations. Digitalization enables ports to optimize operations for reduced emissions and energy consumption, while green shipping practices drive the demand for digital solutions that enhance efficiency and environmental performance.

Fallah et al. (2022) conducted a study on sustainable development goals (SDGs) as a framework for corporate social responsibility (CSR). The study used ANOVA and found that the variations with which energy-efficient vessels are strategic in the literature makes it difficult to grasp the essential attributes. The study also, found that energy-efficient vessel is of critical importance to blue economy because it allows vessels use various technologies and strategies to reduce fuel consumption and emissions.

The demands of the global economy have meant technological innovations have changed and become increasingly important in harnessing the flow of goods (Fardin et al., 2024). Aziz et al. submit that technological innovations are largely seen a cost centre, that is an asset which incurs a cost but does not directly benefit a business.

Many studies have sought to identify and measure the inputs of the energy-efficient vessel; technological innovations and marine transport decarbonization are utilised as strategic hubs of green shipping activities Others have identified elements such as financial investments, patents and commercialization of innovative products and services (Elkafas et al. 2023).

Effect of Decarbonization of Marine Transport on Port Digitalization

Enock (2023) conducted a study on does shipping cause environmental emissions? Evidence from African countries. The study employed correlational analysis and found that energy-efficient vessel activities do not generate substantial environmental externalities that affect surrounding neighborhoods. Using data from the Los Angeles region, his study tests the relationship between the spatial distribution of technological innovations and neighborhoods with different demographic and socioeconomic characteristics. The results show that technological innovations are disproportionately located in both low-income and medium-income minority neighborhoods. The distribution of energy-efficient vessel facilities and activities is highly related to the percentage of minorities as expected, but its relationship with household income is nonetheless mixed. Yui-yip et al. (2024) examined maritime transport resilience: A systematic literature review on the current state of the art, research agenda and future research directions. The study explored extant literature Akbari and Hopkins (2022) examined digital technologies as enablers of supply chain sustainability in an emerging economy. The study analyzed 333 digital technology-innovative firms in South Korea and found that organizational effectiveness significantly affects energy-efficient vessel. Their findings also imply that managers with entrepreneurial orientation and market orientation should emphasize development of blue economy in order to boost energy-efficient vessel and ultimately achieve organizational effectiveness.

Dzhengiz and Niesten, (2020) did a study on competences for environmental sustainability: A systematic review on the impact of absorptive capacity and capabilities. The study revealed that development of blue economy has a positive effect on firm energy-efficient vessel. In addition, energy-efficient vessel was found to positively affect financial performance via the full mediating effect of firm energy-efficient vessel. Durik et al. (2023) point out the indirect impact of energy-efficient vessel on innovation, via innovative culture. The results are also supported by findings of subsequent studies.

Effect of Technological Innovations on Port Digitalization

El-Araby (2024) indicate that energy-efficient vessel hinges on senior management support, as well as an appropriate innovative infrastructure and information and communication technology, leading to organizational effectiveness. This suggests the possibility that survival and exit may be contingent not only on the type of innovation which firms are undertaking but also on how firms are undertaking that innovation, that is, the nature of firms‟ innovation strategies.

However, energy-efficient vessel surveys tend to focus on measures of process inputs and outputs, rather than the process itself or the dynamics that create the innovation (Kim et al., 2024). It has been suggested that the use of input and output indicators of the innovation process is akin to Goodhart's Law, in which any statistical evidence related to a set of indicators tends to degrade as soon as rules are created to improve, not the process, but the indicators themselves (Gangani et al., 2024). Furthermore, macro-level indicators, such as the availability of skilled labor, capital, government regulations, and national culture do not appear as decisive drivers of radical innovation in companies (Gharizadeh et al., 2020). In this sense, further studies are required for a full understanding of the factors that enable organizations to implement innovations in a successful way (Gavalas et al., 2022). Considering the shortcomings of input and output indicators of the innovation process to assess the elements that lead to innovation, such as insufficient attention to internal factors in specific contexts, this study set out to investigate the organizational conditions that enable companies to innovate — defined in this context as Organizational Energy-efficient vessel (OI). Therefore, the present study aimed to develop a theoretical model that identifies OI dimensions, and to verify empirically the model's capacity to evaluate the impact of such dimensions on innovative performance.

Reddy et al. (2024) conducted a study on sustainable vehicles for decarbonizing the transport sector: a comparison of biofuel, electric, fuel cell and solar-powered vehicles. The study used factor analytical tools and found that green shipping practices and port digitalization have a mutually beneficial relationship, with digitalization playing a key role in enabling and enhancing green shipping initiatives. The study also revealed that digital technologies improve operational efficiency, reduce emissions, and optimize resource allocation, ultimately supporting the green development of ports and the broader maritime industry.

The term “energy-efficient vessel” can be seen as the transition involves several strategies, including using alternative fuels, improving vessel efficiency, and adopting new technologies (Al-Mohannadi et al., 2024). United Nations Environment Programme (UNEP). (2021) emphasizes the ability to break established procedures, and thus facilitate the generation of innovative ideas, experimentation, and creativity, which in turn would lead to the development of new products and technologies. Despite the distinction between the two concepts, it is not uncommon to find studies that use the terms as synonymous, applying mixed measures for both innovation and energy-efficient vessel (Longarela-Ares et al., 2020). Hence, the study therefore hypothesizes that: Ho_2: Technological innovations, energy-efficient vessels and decarbonization of marine transport have no significant effect on port digitalization.

MATERIALS AND METHODS

Research Design

This study adopted the ex-post facto research design which requires the usage of historical data to forecast future trends employing regression techniques.

Method of Data Collection

Secondary sources of data were used as the main data collection sources in which accuracy, availability, adequacy, authority, scope, suitability and sources of data were considered for relevance. The relevant data for this study were collected from the annual reports and accounts of Nigerian Ports Authority, NIMASA, Shippers Council, Nigeria Inland Waterways Authority (NIWA), Federal Ministry of Blue Economy and National Bureau of Statistics Annual Statistical Bulletins of the various years in question from their official website. The data collected were from the period of 1990-2024.

Model Specification

This research work adopted the model of Odiegwu and Enyioko (2022a); Felício et al. (2021).; Odiegwu & Zeb-Obipi (2023) with slight modifications (for example; marine tourism, port digitalization, sustainable fisheries and ecological sustainability). The researchers expressed blue economy development (BED) indicators as a function of green shipping practices (GSP). Based on that, the model of the study is stated thus:

$Y = b_o + b_1x_1 + b_2x_2 + b_3x_3 + e$

$PORDIG = ß_0 + ß_1\ ENEGEV + ß_2\ DEMATR + ß_3\ TECHIN + U_t$

Where:

PORDIG = Port Digitalization

ENEGEV= Energy-efficient vessels

DEMATR= Decarbonization of marine transport

TECHIN=Technological innovations

A priori Expectation - The a priori expectations adopted the findings of Felício et al. (2021); Odiegwu and Zeb-Obipi (2023) and Nguyen et al. (2025), which all stated a positive significant effect of independent variables on dependent variables/parameters/indicators.

Techniques of Data Analyses - The data generated/collected was subjected to analysis. The analytical tool used was Eviews 12. Several data analyses techniques were employed for the purposes of analyzing the collected data set and drawing conclusions based on them.

Test for Stationarity - In carrying out this research work, it was important to test the stationarity properties of the time series.

Test for Serial Correlation - In a time, series or panel data model, this is correlation between the errors in different time periods. A series is said to be serially correlated where the data are correlated across time and the errors arise from adjacent time periods.

RESULTS

Presentation of Data

Time series annual data on port digitalization (PORDIG) energy-efficient vessels (ENEGEV), decarbonization of maritime transport (DEMATR) and technological innovations (TECHIN) for Nigeria covering the period from 1990 to 2024 used for this study are presented Table 1 below:

Table 1: Time series annual data on port digitalization, energy-efficient vessels, decarbonization of maritime transport and technological innovations from 1990 to 2024

Year	PORDIG (No. of Major Port Digitalization Initiatives)	ENEGEV (No. of Energy – Efficient Vessels (Approx.)	DEMATR (No. of Decarbonization incentives count)	TECHIN (No. Notable Innovations)
1990	1	1	1	2
1991	1	1	1	2
1992	1	1	2	2
1993	1	1	1	2
1994	1	1	2	2
1995	1	1	2	3

1996	2	1	2	3
1997	2	1	2	3
1998	2	2	3	3
1999	3	3	3	3
2000	3	4	4	5
2001	4	4	3	5
2002	5	4	4	5
2003	5	5	4	5
2004	6	5	5	5
2005	7	5	6	8
2006	8	5	6	8
2007	9	5	7	8
2008	10	5	7	8
2009	11	5	8	8
2010	12	10	9	15
2011	14	10	10	15
2012	15	10	11	20
2013	17	10	12	20
2014	18	10	13	20
2015	20	20	15	30
2016	22	20	16	30
2017	24	20	18	30
2018	26	20	20	40
2019	28	20	22	40
2020	30	30	24	50
2021	35	30	28	50
2022	38	30	30	55
2023	40	40	32	55
2024	42	50	35	60
Sources: Nigerian Ports Authority (NPA), Nigerian Maritime Administration and Safety Agency (NIMASA), Nigerian Shipper's Council (NSC), Nigerian Navy and Marine Police (NNMP), National Inland Waterways Authority (NIWA), Federal Ministry of Marine and Blue Economy (FMMBE).				

Descriptive Statistics

A descriptive analysis of the series was carried out to gain more information on each of the variables. The Table 2 below summarized and organized the characteristics of a total of 35 observations of the dependent variables and independent variables.

Table 2: Descriptive Statistics of the Variables.

	PORDIG	ENEGEV	DEMATR	TECHIN
Mean	13.25714	11.14286	10.51429	17.71429
Median	9.000000	5.000000	7.000000	8.000000
Maximum	42.00000	50.00000	35.00000	60.00000
Minimum	1.000000	1.000000	1.000000	2.000000
Std. Dev.	12.64060	12.36490	9.852952	18.57191

Skewness	0.891514	1.482447	1.080320	1.043935
Kurtosis	2.602234	4.529590	3.023671	2.675297
Jarque-Bera	4.867049	16.23159	6.808844	6.510920
Probability	0.087727	0.000299	0.033226	0.038563
Observations	35	35	35	35

Source: Author’s computation using E-views software, 2025

The descriptive statistics from Table 2 revealed that the mean, minimum, maximum and standard deviation for port digitalization (PORDIG) are 13.25714, 1.000000, 42.00000 and 12.64060 respectively suggesting that the data are convergent to its mean value. Similarly, the mean values for energy-efficient vessels (ENEGEV), decarbonization of marine transport (DEMATR) and technological innovations (TECHIN) are 11.14286, 10.51429 and 17.71429 respectively. The standard deviations showed that the observations for each of the variables are centered around their respective mean values with the exception of ENEGEV and TECHIN whose standard deviations appeared to be greater than their mean values, implying that the data are dispersed around the mean. The kurtosis which measures the peak-ness or flatness of the distribution of the series revealed that PORDIG and TECHIN are platykurtic since their kurtosis values are less than 3 showing they have broad curves and thick tails. The kurtosis of DEMATR is mesokurtic given that the value is approximately 3 indicating that the distribution mirrors normal distribution while the kurtosis of ENEGEV is lepokurtic since the kurtosis value is higher than 3 suggesting a peaked curve. Furthermore, the probability values of the Jarque-Bera statistics of PORDIG revealed that the data are normally distributed at 5 per cent level except for ENEGEV, DEMATR and TECHIN.

The trends of the series which spanned through the study period (1990-2024) are presented to provide more insights into the data distribution in Figure 1

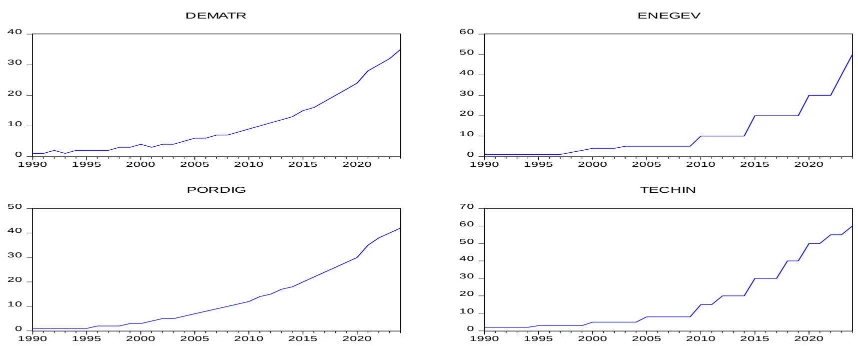

Figure 2: Trend of the Effect of Green Shipping Practices (energy-efficient vessels, decarbonization of marine transport and technological innovations) on port digitalization in Nigeria. (1990-2024).

Sources: Nigerian Port Authority (NPA) and Nigerian Shippers Council (NSC)

From figure 2 port digitalization captured by the number of major port digitalization initiatives in Nigeria has shown a sustained upward trend. It was 1 in 1990 and remained the same until 1996 where it increased to 2 and has continued to trend upwards since then. By 2024, the number of port digitalization initiatives in Nigeria was 42. The increasing adoption of port digitalization initiatives in Nigeria is driven by the need to improve efficiency, reduce costs, and enhance competitiveness in the global maritime industry. Specifically, digitalization aims to streamline operations, improve transparency, reduce bureaucratic bottlenecks and cargo dwell time, all of which contribute to a more efficient and cost-effective port system. It is evident from Figure 1 that the trend of energy efficient vessels in Nigeria has been characterized by steady upward movements. The number of energy efficient vessels was 1 in 1990 and remained so until 1998 where it increased to 2 and continued in that manner. By 2010, the number of energy efficient vessel had increased to 10 and further increased 30 in 2020 and 50 in 2024 respectively.

Data Analysis

Unit Root Test

Unit root tests is crucial in time series analysis to determine if a series is stationary or contains a unit root. A unit root indicates the series is non-stationary, potentially leading to spurious regressions, where relationships between variables appear significant when in fact they are not. Testing for a unit root is a fundamental step to ensure the validity and reliability of econometric models and avoid misleading results. Hence, this study employed the Phillips-Perron (1988) unit root test to examine the order of integration of the variables. The result of the Phillips-Perron test of stationarity at level and first difference are presented in Table 3:

Table 3: Unit Root Test Results.

Variables	PP at Level	Critical value 5%	PP at 1^{st} Diff.	Critical value 5%	Order of Integration
$LPORDIG_t$	-0.749675	-2.951125	-7.291630	-2.954021	1(1)
$LENEGEV_t$	0.483834	-2.951125	-6.511759	-2.954021	1(1)
$LDAMATR_t$	-8.628040	-2.951125	-	-	1(0)
$LTECHIN_t$	0.886557	-2.951125	-11.26185	-2.954021	1(1)

Source: Authors computation from Eviews 12, 2025

From the Phillip-Perron unit root test results in Table 3, it was discovered that e decarbonization of marine transport DEMATR was stationary at level that is integrated of order zero I(0). However, other variables port digitalization PORDIG, energy efficient vessels ENEGEV and technological innovations TECHIN) became stationary at first difference that is integrated of order one I(1). Given the mixed order of integration of the series I(0) and I(1), the autoregressive distributed lag (ARDL) model was employed.

Model Estimation

Following the evidence of mixed order of integration and the presence of long run relationship amongst the variables examined, the autoregressive distributed lag (ARDL) model was estimated to analyze the behaviour of the variable in the long run and short run and the speed of adjustment to long run equilibrium in model (PORDIG). The results are presented in Table 4:

Table 4: ARDL Estimates for Port Digitalization (PORDIG) Model.

Dependent Variable: LOGPORDIG				
Variable	**Coefficient**	**Std. Error**	**t – Stats**	**Prob.**
Short Run Estimates				
D(LENEGEV)	0.1616	0.0334	4.8390	0.0019
D(LDEMATR)	0.4533	0.1027	4.4129	0.0031
D(LTECHIN)	0.2769	0.0558	4.9589	0.0016
CointEq(-1)	-0.3933	0.0251	-15.642	0.0000
Variable	**Coefficient**	**Std. Error**	**t – Stats**	**Prob.**
Long Run Estimates				
LENEGEV	0.3492	0.1704	2.0482	0.0797
LDEMATR	1.0561	0.2308	4.5748	0.0026
LTECHIN	0.5905	0.2009	2.9390	0.0217
C	1.7925	0.4444	4.0329	0.0050
R-Squared	0.9940	Durbin-Watson Stat.	1.9554	
Source: Author’s compilation from output of E-Views 12, 2025				

Short Run Results

The short run results from Table 4.6 revealed that energy-efficient vessel (ENEGEV) has a positive effect on port digitalization (PORDIG) in Nigeria indicating that one percent increase in energy efficient vessel will lead to 0.1616 percent increase in port digitalization. This result is consistent with a priori expectation of the study. In addition, the result was found to be statistically significant at 0.05 level given the associated probability value of 0.0019. The findings also showed that decarbonization of maritime transport (DEMATR) has a positive and significant effect on port digitalization (PORDIG) suggesting that a percent increase in decarbonization of maritime transport leads to an increase in port digitalization by 0.4533 percent indicating conformity with a priori expectation.

The estimated coefficient of technological innovation (TECHIN) appeared positively signed and exert a significant effect on port digitalization in Nigeria given the associated probability value of 0.0016. The result implies that a percent increase in technological innovation will lead to an increase in port digitalization by 0.2769 percent, this outcome is consistent with theoretical expectation.

Long Run Results

The long run results revealed that energy-efficient vessel has an insignificant positive effect on port digitalization in Nigeria suggesting that one percent increase in energy-efficient vessel is associated with 0.3492 percent increase in port digitalization. This finding is similar to the behaviour of energy-efficient vessel in the short run. Additionally, the effect of energy-efficient vessel on port digitalization is higher in the long run compared to its effect in the short run. Also, the finding is consistent with a priori expectation of the study.

For decarbonization of maritime transport, its coefficient appeared positively signed and exert a significant effect on port digitalization in Nigeria highlighting that one percent increase in decarbonization of maritime transport will lead to an increase in port digitalization by 1.0561 percent, this outcome is in conformity with theoretical expectation.

Also, the long run estimate revealed that technological innovation has a positive and statistically significant relationship with port digitalization in Nigeria indicating that a percent increase in technological innovation will increase port digitalization by 0.5905 percent. This result shows that the relationship between technological innovation and port digitalization conforms to a priori expectation of the study.

The coefficient of determination (R^2) is estimated at 0.9940 which implies that 99.4 percent of the variations in port digitalization is explained by the independent variables examined in the model (energy efficient vessel, decarbonization of maritime transport and technological innovation) indicating a very good fit as the model captures most of the variability in the data.

Also, the Durbin-Watson Statistics value of 1.9554 falls within the acceptable range indicating that there is no autocorrelation in the residuals. Furthermore, the error correction coefficient is negative (-0.3933) and statistically significant with a probability value of 0.0000 indicating that the model can adjust to long run equilibrium position at a speed of 39.33 percent.

Post-estimation Tests

The study carried out post diagnostic test to ascertain whether the empirical results are reliable and suitable for policy application and recommendation.

Table 4: Inspection of CLRM Assumptions.

Source: Author's compilation from output of E-Views 10, 2025

Tests	CLRM Problem	Test Stats.	Prob.	Decision
Breusch-GodfreyLM	Serial Correlation	0.1116	0.7382	Serial independence
Breusch-Pagan-Godfrey	Heteroscedasticity	22.860	0.3514	Constant Variance
Jarque Bera	Normality Test	0.3203	0.8519	normally Distributed
Ramsey RESET	Model Specification	3.9728	0.0933	Model is not misspecified
CUSUM	Stability	-	-	Model is Stable

Source: Author's compilation from output of E-Views 12, 2025

DISCUSSION

Effect of Energy-Efficient Vessels on Marine Tourism in Nigeria The result of the short run estimate shows that energy-efficient vessel (ENEGEV) has positive effect on port digitalization (PORDIG) in Nigeria indicating that one percent increase in energy-efficient vessels lead to a 0.1616 percent increase in port digitalization in the short run. This finding is synonymous with the long run estimate which revealed that energy-efficient vessel has positive effect on port digitalization. This implies that one percent increase in energy-efficient vessels contributes to port digitalization by 0.3492 suggesting that the adoption of green vessels prompts the need for compatible digital port infrastructure. The estimated coefficients of energy-efficient vessels showed it is consistent with a priori expectation of the study and supported by IMO (2020), which emphasized the importance of vessel-port digital integration in achieving emission targets and smart port development. Furthermore, the positive effect of energy-efficient vessels was found to be statistically significant only in the short run at 0.05 level as indicated by its associate probability value of 0.0019. Therefore, the study rejects the null hypothesis and conclude that energy-efficient vessel has a positive and significant effect on port digitalization in Nigeria.

Effect of Decarbonization of Marine Transport on Marine Tourism in Nigeria

The short run result showed that decarbonization of maritime transport (DEMATR) has positive effect on port digitalization (PORDIG) in Nigeria which indicates that one percent increase in decarbonization of maritime transport is associated with 0.4533 increase in port digitalization. This outcome is similar to the long run result that shows that decarbonization of maritime transport has positive effect on port digitalization highlighting that decarbonization acts as both a compliance driver and a strategic enabler, pushing ports to adopt digital solutions that improve efficiency and sustainability in the short term, and transform port infrastructure for long-term climate resilience and operational excellence. These findings conform to theoretical expectation and in tandem with Tsimplis et al. (2016) who asserted that stricter emission and sustainability standards push ports toward digital monitoring, emission tracking systems, and compliance technology. Also supported by Kurniawan et al. (2018) who highlighted that sustainable transport policies create demand for digital systems to manage environmental performance. In addition, the positive effect of decarbonization of maritime transport on port digitalization both in the short run and long run was found to be statistically significant at 0.05 significance level given the corresponding probability values of 0.0031 and 0.0026 respectively. Hence, the study rejects the null hypothesis since the probability values are less than 0.05. Based on the short run and long run results, the study submits that decarbonization of maritime transport has significant positive effect on port digitalization in Nigeria.

Effect of Technological Innovations on Marine Tourism in Nigeria

The short run and long run estimated coefficient of technological innovation (TECHIN) revealed it has positive effect on port digitalization (PORDIG) in Nigeria which is consistent with a priori expectation of the study. The results imply that a one percent improvement in technological innovation boost port digitalization by 0.2769 percent and 0.5905 percent in the short run and long run respectively suggesting that technological innovations lead to increased efficiency, reduced costs, and improved transparency in port operations which foster sustainable growth, enhance competitiveness, and drive the development of smart and resilient port ecosystems. This result is supported by OECD (2020) who highlighted that innovation is a key driver of smart port transformation, essential for efficiency and competitiveness. Additionally, the positive effect of technological innovation on port digitalization was found to be statistically significant in the short run and long run given the associated probability values of 0.0016 and 0.0217 respectively. Hence, the study rejects the null hypothesis and submit that technological innovation has a positive and significant effect on port digitalization in Nigeria.

CONCLUSION

The findings underscore the pivotal role of green shipping practices in advancing Nigeria's port digitalization agenda. Among the practices, decarbonization of maritime transport emerges as the most influential, delivering immediate and sustained environmental benefits across the three-variables examined. Technological innovation and energy-efficient vessels also significantly contribute positively to the development of port digitalization in Nigeria. Green shipping practices in Nigeria are not just an environmental imperative but a strategic enabler for port digitalization.

RECOMMENDATIONS

Based on the empirical findings, the following policy recommendations have been made:

1. Government should encourage the acquisition of energy-efficient vessels and decarbonization of maritime transport system to align with technological innovations development of the maritime sector.
2. Also, regulatory frameworks should prioritize carbon reduction strategies, including stricter emission controls and incentives for low-carbon shipping practices.
3. Government and maritime stakeholders should focus efforts on channeling and leveraging on digital solutions for port digitalization, operational efficiency, and workforce development. s.

REFERENCES

1. Adeleke, B., Adedoyin, F., & Alola, A. A. (2019). Environmental quality effects of income, energy prices, and trade: The role of renewable energy consumption in G-7 countries. Environmental Science and Pollution Research, 26(1), 1328–1339. https://doi.org/10.1007/s11356-018-3763-1
2. Ajayi, A P. (2024). Blue Economy and Integrated Transport System as a Game Changer to Nigeria's Economic Challenges. 14. 22-33.
3. Akomolafe, T. D, Yerokun, O. M, & Akande, S (2022). Challenges and prospects of the deployment of blue economy in the coastal areas of Ondo State. Journal of Production, Operations and Management Economics. 2(3), 10 -23.
4. Akujor, C.E, Uzowuru, E.E, Abubakar, S.S. & Amakom C.M., (2022). Decarbonisation of the Transport Sector in Nigeria. Environ Health Insights. Sep

23;16:11786302221125039. doi: 10.1177/11786302221125039. PMID: 36185498; PMCID: PMC9520152.

5. Akujuru, C. A. & Enyioko, N. C. (2018). Social science research: Methodology and conceptual perspectives. Beau Bassin: Lambert Academic Publishing
6. Ali, K.A. (2023). Sustainable blue economy and its impact on economic growth in Africa.
7. Case study: Zanzibar State: International Journal of Recent Research in Commerce Economics and Management (IJRRCEM),10(2),1-12.
8. Ahmed Ali, K., Ahmad, M. I., & Yusup, Y. (2020). Issues, Impacts, and Mitigations of
9. Carbon Dioxide Emissions in the Building Sector. Sustainability, 12 (18), 7427. https://doi.org/10.3390/su12187427
10. Aminul I, Tarekul I, Hasan M, Obayed R, Md. Shahinoor I, Hadi M. M, Mohammed M. R,
11. Abdullah M. A, Md. Munjur H, Md. Nazmul H, Md. S S, Khadiza T K,. Shenashen M.A, Md. Chanmiya S, M. & Rabiul A. (2024). Accelerating the green hydrogen revolution: A comprehensive analysis of technological advancements and policy interventions, International Journal of Hydrogen Energy, 67, 458-486.
12. Anthony F, George G. Z, Troy R. & Hawkins, E N, (2021). Challenges and opportunities for alternative fuels in the maritime sector, Maritime Transport Research, 2, 20-37.
13. Atedhor, G.O. (2023). Greenhouse gases emissions and their reduction strategies:
14. Perspectives of Africa's largest economy, Scientific African, Volume 20, e01705, ISSN 2468-2276.
15. Barbu A, Catană ȘA, Deselnicu DC, Cioca LI. & Ioanid, A. (2022). Factors Influencing Consumer Behavior toward Green Products: A Systematic Literature Review. Int J Environ Res Public Health. 19 (24):16568. doi: 10.3390/ijerph192416568. PMID: 36554445; PMCID: PMC9778922.
16. Barone G, Annamaria B., Gianluca, D., Robert M. & Adolfo, P. (2024). Approaching zero emissions in ports: implementation of batteries and supercapacitors with smart energy management in hybrid ships, Energy Conversion and Management, 314, 118446, ISSN 0196-8904.
17. Bofan W, Zhao J T. & Ming Z. (2024). Sustainable aviation fuels: Key opportunities and challenges in lowering carbon emissions for aviation industry, Carbon Capture Science & Technology, 13 (1), 100263, ISSN 2772-6568.

18. Carter B. C, Alessandra C. & Luisa G. (2024). Public-private partnerships for low-carbon, climate-resilient infrastructure: Insights from the literature, Journal of Cleaner Production, 47(0), 143338, ISSN 0959-6526,
19. Chang, Y.-T., & Danao, D. (2017). Green Shipping Practices of Shipping Firms. Sustainability, 9(5), 829. https://doi.org/10.3390/su9050829
20. Coupe, L. (2013). Green theory in The Routledge Companion to Critical and Cultural Theory. 2nd edn. Routledge. Dzhengiz, T. & Niesten, E. (2020).
21. Competences for environmental sustainability: A systematic review on the impact of absorptive capacity and capabilities. Journal of business ethics, 162 (4), 881-906.
22. Elegbede, I. O., Akintole, S. L. & Jimoh, A. (2023). Blue economy (sustainability), DOI: 10.1007/978-3- 030-02006-4_401-1.
23. Elisha, O. D (2019). The Nigeria blue economy: Prospects for economic growth and challenges. International Journal of Scientific Research in Education, 12(5), 680-699.
24. El-Omda S, Sergent SR. Standard Deviation. (2025). Stat Pearls [Internet]. Treasure Island (FL): Stat Pearls Publishing; 2025 Jan-. https://www.ncbi.nlm.nih.gov/books/NBK574574/
25. Emeka O, S, Otonnah, C., & Nwankwo, E. (2024). Review 0f Carbon Pricing Mechanisms: Effectiveness and Policy Implications. International Journal of Applied Research in Social Sciences. 6 (0), 337-347. 10.51594/ijarss.v6i3.891.
26. Enyioko, N. C. & Amadi, S. N. (2025). Effect of monetary, fiscal and trade policies on economic stabilization in Nigeria. SSRN: https://ssrn.com/abstract=5309473. 5(7), 1-21
27. Felício, J. A., Rodrigues, R., & Caldeirinha, V. (2021). Green Shipping Effect on Sustainable Economy and Environmental Performance. Sustainability, 13(8), 4256. https://doi.org/10.3390/su13084256
28. Ganeshu, P., Fernando, T., & Keraminiyage, K. (2023). Barriers to, and Enablers for, Stakeholder Collaboration in Risk-Sensitive Urban Planning: A Systematised Literature Review. Sustainability, 15(5), 4600. https://doi.org/10.3390/su15054600
29. Gavalas, D., Syriopoulos, T. & Roumpis, E. (2022). Digital adoption and efficiency in the maritime industry. J. shipp. trd. 7, 11 https://doi.org/10.1186/s41072-022-00111-y
30. Giovanni B, Annamaria B, Gianluca D P, Robert M. & Adolfo P. (2024). Approaching zero emissions in ports: implementation of batteries and supercapacitors with smart energy management in hybrid ships, Energy Conversion and Management, 314, 118446, ISSN 0196-8904.

31. Giwa F. (2018). PPP and Nigeria's budding blue economy a perfect Match? Journal of Sustainable Economy, 3(1), 16-22.

32. Glavinović, R., Krčum, M., Vukić, L., & Karin, I. (2023). Cold Ironing Implementation Overview in European Ports—Case Study—Croatian Ports. Sustainability, 15(11), 8472. https://doi.org/10.3390/su15118472

33. Hassan, T. M. Y., Emam, E. M. A., & Mohammed, A. R. N. (2024). Implementation of green freight transport approach in Egypt: A case study of Port Said ports. South Valley University Scientific Research Conference, South Valley.

34. Hussein, M., Kennedy, A., & Oliver, B. (2017). Grounded theory and the Conundrum of literature review. The Qualitative Report, 22(4), 1199–1211.

35. IMO (2018). Adoption of the initial IMO strategy on reduction of GHG emissions from ships and existing IMO activity related to reducing GHG emissions in the shipping sector, April 13. London: IMO.

36. IMO (2021). IMO working group agrees guidelines to support new GHG Measures https://www.imo.org/en/MediaCentre/PressBriefings/pages/ISWG-GHG-8.aspx (2021)

37. IMO (2024). Maritime safety in an era of new technologies and alternative fuels. International Maritime OrganizationPublication DOI: https://doi.org/10.82454/KG596p, 10(5), 23-51

38. Jacob, A.O & Umoh, O.J. (2022). The Nigerian blue economy: Economic expansion issues and challenges, Socio Economy and Policy Studies (SEPS) 2(1),29-33

39. Jakobsen K, Marius M. & Grethe L. (2023). A literature review of smart technology domains with implications for research on smart rural communities, Technology in Society, Volume 75, 102397, ISSN 0160-791X.

40. James, C (2011). *Theory of Change Review: Report Commissioned by Comic Relief*. http://maride.couk/blogcom.theoryofchangereview-final, 3(6)29-46

41. Jinggai W, Huanhuan L, Zaili Y. & Ying-En G. (2024). Shore power for reduction of shipping emission in port: A bibliometric analysis, Transportation Research Part E: Logistics and Transportation Review, 18(8), 103639, https://doi.org/10.1016/j.tre.2024.103639.

42. Karagkouni, K., & Boile, M. (2024). Classification of Green Practices Implemented in Ports: The Application of Green Technologies, Tools, and Strategies. Journal of Marine Science and Engineering, 12(4), 571. https://doi.org/10.3390/jmse12040571

43. Kee-Hung L, Venus Y.H, Christina W.Y, Wong, T.C. & Cheng E. (2011). Green shipping practices in the shipping industry: Conceptualization, adoption, and implications, Resources, Conservation and Recycling, 55(6), 631-638, ISSN 0921-3449.
44. Kolich, D. & Kurtovic, F. (2021). LNG vs. Scrubber Technology in Future Green Ships.
45. https://www.bib.irb.hr/1032238/download/1032238.Kolich_Kurtovic-SMATECH_2019.pdf (accessed on 21 August 2021)
46. Kolios, A. (2024). Retrofitting Technologies for Eco-Friendly Ship Structures: A Risk Analysis Perspective. Journal of Marine Science and Engineering, 12(4), 679. https://doi.org/10.3390/jmse12040679
47. Lee, K.-H., Noh, J. & Khim, J. S. (2020). The blue economy and the United Nations' sustainable development goals: challenges and opportunities. Environment International, 137, 105528.
48. Livaniou, S., & Papadopoulos, G. A. (2022). Liquefied Natural Gas (LNG) as a Transitional Choice Replacing Marine Conventional Fuels (Heavy Fuel Oil/Marine Diesel Oil), towards the Era of Decarbonisation. Sustainability, 14(24), 16364. https://doi.org/10.3390/su142416364
49. Luis A D, R. González, N. Rivera, Elena M & José R Q, (2023). Waste heat recovery system for marine engines optimized through a preference learning rank function embedded into a Bayesian optimizer, Ocean Engineering, 28(1), 114747, ISSN 0029-8018,
50. Mander S. (2017). Slow steaming and a new dawn for wind propulsion: A multi-level analysis of two low carbon shipping transitions, Marine Policy, Volume 75, 2017, Pages 210-216
51. Manuel C, Roberto R H & Ning L. (2023). Adopting different wind-assisted ship propulsion technologies as fleet retrofit: An agent-based modelling approach, Technological Forecasting and Social Change, 192, 2023, 122559, ISSN 0040-1625.
52. Maqsood A, Xiaohui F. L. & Qiang, W. (2024). Carbon taxes and emission trading systems: Which one is more effective in reducing carbon emissions?—A meta-analysis, Journal of Cleaner Production, Volume 476, 143761, ISSN 0959-6526.
53. Mi, J. J., Wang, Y., Zhang, N., Zhang, C., & Ge, J. (2024). A Bibliometric Analysis of Green Shipping: Research Progress and Challenges for Sustainable Maritime Transport. Journal of Marine Science and Engineering, 12(10), 1787. https://doi.org/10.3390/jmse12101787

54. Mikalai F, Michael P, Peterson, H Y, Andrei G, Lifeng Z & Yi H. (2024). Greenhouse gas emissions and reduction strategies for the world's largest greenhouse gas emitters, Science of The Total Environment, Volume 944, 2024, 173895, ISSN 0048-9697.
55. Nguyen, T. M. A., Khoa, V. D., Giang, P. T. H., & Toan, D. V. (2025).
56. The impact of green logistics practices on sustainable performance: An empirical study of small and medium logistics service providers in Hanoi. International Journal of Scientific Research and Management, 13(1), 12 – 26.
57. Nusraningrum, D., Mekar, T. M., Endri, E., & Ahmad, F. S. (2023). Does implementing green operation management affect the sustainability of port operations in Labuan Bajo? Uncertain Supply Chain Management, 11(4), 1417–1426
58. Nwokolo, S. C., Meyer, E. L., & Ahia, C. C. (2023). Credible Pathways to Catching Up with Climate Goals in Nigeria. Climate, 11(9), 196. https://doi.org/10.3390/cli11090196
59. Odiegwu, C. L. & Enyioko, N. C. (2022a). Effect of abandoned vessels on safety of mariners in coastal waters of Nigeria. International Research Journal of Modernization in Engineering Technology and Science4 (8) 2352 – 2370 www.irjmets.com.
60. Odiegwu, C. L. & Enyioko, N. C. (2022b). Influence of sustainable shipping on organizational effectiveness of shipping companies in Port Harcourt Nigeria. International Journal of Research and Innovation in Social Science (IJRISS) VI VIII 74-92.
61. Odiegwu, C. L. & Zeb-Obipi (2023). Effect of international seaborne trade on productivity of ports in Nigeria.
62. SSRN: https://ssrn.com/abstract=4619783 or http://dx.doi.org /10.2139/ssrn.4619783, i-xxxviii
63. Olakunle O, Kasypi M, Norlinda M R, Adel G, Saira A. & Lai F C. (2023) Effective technologies and practices for reducing pollution in warehouses - A review, Cleaner Engineering and Technology, Volume 13, 100622, ISSN 2666-7908.
64. Olaniyi E O., Maria C S, Tommi I. (2024). Smart regulations in maritime governance: Efficacy, gaps, and stakeholder perspectives, Marine Pollution Bulletin, 202, 2024, 116341, ISSN 0025-326X.
65. Omai, K. M. & Ngugi, P.K. (2018). Effect of supply chain practices on sustainable supply chain performance in Kenyan textile and apparel industry. International Journal of Economics, Commerce and Management, 6(8), 443-446.
66. Osuji, J. N. & Agbakwru, J. (2024). Ocean and coastal resources components and their contributions to sustainable development of Nigeria, Journal of Applied Science and Environmental Management, 28 (1) 135-146:https://dx.doi.org/10.4314/jasem.v28i1.16.

67. Ozili, P. K. (2024). Does banking sector support for achieving the sustainable development goals affect bank loan loss provisions? International evidence. Economic Change and Restructuring, 57(2), 66.
68. Pelić, V., Bukovac, O., Radonja, R., & Degiuli, N. (2023). The Impact of Slow Steaming on Fuel Consumption and CO2 Emissions of a Container Ship. Journal of Marine Science and Engineering, 11(3), 675. https://doi.org/10.3390/jmse11030675.
69. Poi, E.L. & Moko, D. (2023). Sustainable shipping practices and supply chain performance of shipping firms in South-South Nigeria. International Academy Journal of Management, Marketing and Entrepreneurial Studies, 9 (2), 28-43.
70. Popoola O. O, & Olajuyigbe, A. E (2023) Operationalizing the blue economy in the Gulf of Guinea, Africa Frontiers for Political Science, 5:1070508. doi:10.3389/fpos.2023.1070508. 1- 20.
71. Rok S, Alexandra D, John L. J. & Colin A. W. (2024). Techno-economic analysis of zero-carbon ammonia-hydrogen fuel blend production through a catalytic membrane reformer and packed bed reactor, Renewable and Sustainable Energy Reviews, 199(1), 114469, ISSN 1364-0321.
72. Selma A, Sunhwa P, Mahmoud M E, Mert A, Margaux M. & Rasmus B N. (2021). Green hydrogen as an alternative fuel for the shipping industry, Current Opinion in Chemical Engineering, 31(1), 2021, 100668, ISSN 2211-3398.
73. Serra, P., & Fancello, G. (2020). Towards the IMO's GHG Goals: A Critical Overview of the Perspectives and Challenges of the Main Options for Decarbonizing International Shipping. Sustainability, 12(8), 3220. https://doi.org/10.3390/su12083220
74. Song, D. -P. (2024). A Literature Review of Seaport Decarbonisation: Solution Measures and Roadmap to Net Zero. Sustainability, 16(4), 1620. https://doi.org/10.3390/su16041620
75. Stark, C., Xu, Y., Zhang, M., Yuan, Z., Tao, L., & Shi, W. (2022). Study on Applicability of Energy-Saving Devices to Hydrogen Fuel Cell-Powered Ships. Journal of Marine Science and Engineering, 10(3), 388. https://doi.org/10.3390/jmse10030388
76. Tadros, M., Ventura, M., & Guedes, S. C. (2023). Review of the Decision Support Methods Used in Optimizing Ship Hulls towards Improving Energy Efficiency. Journal of Marine Science and Engineering, 11(4), 835. https://doi.org/10.3390/jmse11040835
77. Taplin, D., Clark, H., Collins, E & Colby, D. L. (2013). *Theory of Change Technical Papers: A Series of Papers to support Development of Theories of change Based on Practice in the Field*. New York: *Acknowledge*,9(5), 38-67

78. Thalis P.V. Zis, Harilaos N. Psaraftis, Fabian Tillig, Jonas W. Ringsberg. (2020).
79. Decarbonizing maritime transport: A Ro-Pax case study, Research in Transportation Business & Management, 37(1), 100565, ISSN 2210-5395.
80. UNCTAD. (2021). Review of Maritime Transport 2021. United Nations Conference on Trade and Development. https://unctad.org/webflyer/review-maritime-transport-2021
81. UNEP, (2024). Blue economy: Report of the United Nations Conference on Sustainable Development. United Nations Environment Programme. https://wedocs.unep.org/bitstream/handle/20.500.11822/15420/BG-Blue%20Economy2013.pdf
82. Varriale, V., Cammarano, A., Michelino, F., & Caputo, M. (2021). Sustainable Supply Chains with Blockchain, IoT and RFID: A Simulation on Order Management. *Sustainability*, *13*(11), 6372. https://doi.org/10.3390/su13116372
83. Wake, P. & Malpas, S. (2013). The Routledge Companion to Critical and Cultural Theory.
84. Oxford, UNITED KINGDOM: Taylor & Francis Group. http://ebookcentral.proquest.com/lib/open/detail.action?docID=1221495 .
85. Weiss, C. (1995). *Nothing as Practical as Good Theory: Exploring Theory-Based Evaluation for Comprehensive Community Initiatives for Children and Families* in 'New Approaches to Evaluating Community Initiatives'. Aspen Institute. 6 (7), 41-57
86. Wenhai, L., Cusack, C., Baker, M., Tao, W., Mingbao, C., Paige, K., Xiaofan, Z., Levin, L., Escobar, E., Amon, D., Yue, Y., Reitz, A., Neves, A. A., O'Rourke, E., Mannarini, G.,Pearlman, J., Tinker, J., Horsburgh, K. J., Lehodey, P. & Yufeng, Y. (2019). Successful blue economy examples with an emphasis on international perspectives. Frontiers in Marine Science, 6. https://doi.org/10.3389/fmars.2019.00261
87. World Bank (2022). Blue economy in Africa: A synthesis, World Bank Policy Brief, www.worldbank.org.
88. Yin X, Lu Y, Zou J. & Wan L. (2019). Numerical and experimental study on hydrodynamic bulbous bow hull-form optimization for various service conditions due to slow steaming of container vessel. Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment. 233(4), 1103-1122. doi:10.1177/1475090218811782.
89. Yin, W.; Wu, S.; Zhao, X.; Shu, C.; Xiao, Y.; Ye, G.; Shi, W. & Feng, X. (2022). Shore power management for green shipping under international river transportation. Maritime. Policy Management, 49, 737–754.

90. M. (2023). Blue economy literature review, International Journal of Business and Management; 18(3), 12-18.

91. Yuan, C.; Pan, P.; Sun, Y.; Yan, X. & Tang, X. (2021). The evaluating on EEDI and fuel consumption of an inland river 800PCC integrated with solar photovoltaic system. Journal of Marine Engineering Technology, 20, 77–92.

92. Yui-yip L, Qiong C, Mark C P, Adolf K.Y. N. & Chung, C. Y. (2024). Maritime transport resilience: A systematic literature review on the current state of the art, research agenda and future research directions, Ocean & Coastal Management, 251(1), 107086, ISSN 0964-5691.