sustainability

MDPI

Article

Redefining Port Concession Agreements: A Framework for Environmental Sustainability

Charalampos Platias [1,*], Constantinos Chlomoudis [2], Petros Pallis [3], Markos Tozidis [2] and Virginia Zarakeli [2]

[1] Department of International and European Studies, Panteion University of Social & Political Sciences, 17671 Athens, Greece
[2] Department of Maritime Studies, University of Piraeus, 18534 Piraeus, Greece; chlom@unipi.gr (C.C.); martoz@unipi.com (M.T.); vzarakeli@unipi.com (V.Z.)
[3] Department of Shipping, Trade and Transport, University of the Aegean, 82132 Rhodes, Greece; ppallis@aegean.gr
* Correspondence: ch.platias@panteion.gr

Abstract: This paper investigates the integration of environmental sustainability into port concession agreements, addressing mounting environmental challenges and the increasing emphasis on sustainability. Traditionally shaped by economic considerations, these agreements now require a more integrated approach that incorporates environmental sustainability as a core principle. The objective is to identify essential environmental requirements that should be embedded in these agreements to drive significant environmental progress in port operations and development. The methodology includes a comprehensive literature review and an empirical analysis of available concession agreements and reference texts, systematically categorizing critical environmental parameters and performance indicators. The key findings highlight the need for port concession agreements to extend beyond regulatory compliance by incorporating proactive sustainability strategies, imposing clear obligations on concessionaires, and defining relevant key performance indicators (KPIs) for effective monitoring. While awareness of environmental impacts in port concession agreements is increasing, significant progress is still needed to fully integrate sustainability into these frameworks. This paper advocates for a shift toward innovative, forward-thinking approaches that align with both environmental and market realities.

Keywords: concession agreements; ports; environmental considerations; sustainability; KPIs

Received: 8 December 2024
Revised: 26 February 2025
Accepted: 10 March 2025
Published: 14 March 2025

Citation: Platias, C.; Chlomoudis, C.; Pallis, P.; Tozidis, M.; Zarakeli, V. Redefining Port Concession Agreements: A Framework for Environmental Sustainability. *Sustainability* **2025**, *17*, 2550. https://doi.org/10.3390/su17062550

1. Introduction

In recent years, ports have faced mounting pressure from local communities, states, and regulatory bodies to address the environmental impact of their operation and development [1–4]. Pollution, habitat destruction, conflicts over land/sea use or activities, congestion, and greenhouse gas emissions linked to port activities have raised concerns about public health and well-being, environmental degradation, and climate change. Port expansion, the intensifying of existing port activities, and the engagement in new ones, as well as port development, create significant challenges [5–8]. Consequently, there is a growing expectation for ports to mitigate their environmental footprint and embrace sustainable strategies and practices [9–15].

Port concession agreements are generally used to attract private investment and transport flows, enhance operational efficiency, strengthen a port's market position and competitiveness, steer port development, and balance public control with private sector

expertise. They govern the terms of private sector involvement in port operations and development and can serve as port governance tools [16], thereby also playing a pivotal role in shaping environmental standards and practices. However, historically, these agreements have prioritized economic objectives over environmental considerations [17–20]. The emphasis on sustainability and the integration of its environmental dimension into the port industry pose substantial challenges for the sector [21], also extending to port concession agreements [17,22]. As a result, there is a need for policymakers and port authorities to proactively define environmental standards that surpass mere compliance with existing legislation.

Within the framework of concession agreements, it falls upon states and port authorities to establish environmental standards and ensure their enforcement. These standards should not only meet current legal requirements but also align with broader environmental goals and strategies outlined by policymakers and stakeholders. By embedding environmental considerations into concession agreements, policymakers can reduce environmental impact, mitigate environmental risks, promote environmental sustainability, and safeguard the interests of local communities and ecosystems [9]. However, achieving this alignment poses challenges, including reconciling economic imperatives with environmental objectives, adhering to evolving regulatory standards, and defining measurable environmental performance indicators [23–27]. As sustainable management and economic benefits in the port sector continue to appear misaligned for significant segments of the industry [28], private entities may hesitate to adopt costly environmental measures or take on additional burdens, making some resistance likely.

In light of these complexities, this research aims to systematically identify and examine environmental requirements and relevant key performance indicators (KPIs) that should be incorporated into port concession agreements. By advocating for the integration of sustainable strategies and practices, this paper offers insights into transition towards environmentally responsible port operations while balancing the interests of all stakeholders involved, including local communities, states, port authorities, and private sector entities.

The originality of this paper lies in its specific focus on integrating environmental sustainability into port concession agreements, an area that has received surprisingly little attention in existing research. This study provides a comprehensive and systematic examination of environmental parameters and KPIs, translating them into concrete obligations for concessionaires while offering an in-depth analysis and extended discussion of relevant issues. Furthermore, this research follows a four-tier approach, incorporating expert input, literature analysis, the examination of available concession agreements, and the review of reference texts, as outlined in Section 3. This multifaceted methodology ensures a well-rounded understanding of the topic and distinguishes this study from previous research.

This paper is part of an ongoing, broader research project on sustainable port concession agreements, serving as a follow-up to the conceptual groundwork established in the academic paper titled "Advancing port sustainability: Essentials for a model concession agreement framework" [17]. In this previous research, the authors identified and analyzed fundamental sustainability requirements and key parameters across the economic, social, and environmental pillars of sustainable development, with the goal of proposing a reference framework for model concession agreements. This framework informs the approach taken in the current paper, which delves deeper into environmental considerations within port concession agreements, with a strong emphasis on environmental sustainability. While the current paper builds on findings from the previous research, it stands as fully independent research, identifying, specifying, and discussing environmental parameters, variables, indicators, and critical issues related to concession agreements in the sector.

Following the introductory remarks in Section 1, this paper is structured as follows: Section 2 offers a comprehensive review of the relevant literature, considering key papers and their contributions to the topic of environmental sustainability in ports and concession agreements. Section 3 explains the methodology and materials employed in this research, detailing the analytical approach and data sources. Section 4 presents the key findings from the analysis, focusing on environmental parameters, variables, and KPIs identified in the literature, as well as in the concession agreements and reference texts examined. In Section 5, these findings are contextualized and discussed within a broader evaluative framework. Finally, Section 6 draws conclusions from the analysis and suggests future directions for research and policy development.

2. Literature Review

Over the last two decades, there has been a notable increase in environmental research, leading to a substantial body of literature focused on environmental sustainability in port operations and development. Systematic literature reviews have consistently underscored the importance of environmental considerations for sustainable port performance [28–33]. Scholars conducting systematic literature reviews on environmental dimensions in port performance emphasize the need to address environmental sustainability as a central element and identify critical parameters essential for environmental performance, with attention to integrating these within overall port operations and strategies [27,34–36]. Additionally, some researchers, through systematic reviews, have identified environmental sustainability as integral to the "smart port" concept, which combines advanced technologies and eco-efficiency to enhance port performance holistically [37–40]. In addition, many scholars provide overviews of environmental considerations in ports, emphasizing the need to address these issues effectively [5–8,13,14,41–45]. They also connect these considerations with overall port performance and sustainability strategies [46–49] and discuss relevant indicators [23,26,50–54]. However, existing research efforts have often focused on specific relevant issues rather than offering a comprehensive picture—an endeavor complicated by the diversity and complexity of the port industry, with its various terminals and activities.

The connection between port sustainability and the United Nations' Sustainable Development Goals (SDGs) was examined by Alamoush et al. [10], who found notable parallels between the two. Ports are not isolated entities; they are embedded within complex systems where global regulations, national policies, and regional standards converge. According to the authors, the nature and role of ports necessitate a comprehensive sustainability framework that accounts for these broader influences. Port operations are shaped by their political, geographic, and regulatory contexts, which influence how they manage and implement sustainability measures effectively. This perspective underscores the importance of considering a port's unique setting.

Establishing a port as a "green port" has become a critical step for modern port development. However, this requires implementing several measures such as environmental monitoring, environmental clauses in concession agreements, stakeholder engagement, energy efficiency improvements, the adoption of cold ironing for ship handling, and the use of innovative technologies. Research on "green" port performance was also conducted by Arof et al. [23], who used terms like "green port" and "sustainable port" to identify performance indices and determinants. Balić et al. [31] focused on the environmental impact of passenger seaports, analyzing literature from 2012 to 2022, with most studies using quantitative methods. Davarzani et al. [36] used bibliometric and network analysis to assess the evolution of the "green ports and maritime logistics" literature. From a managerial perspective, Di Vaio and Varriale [55] suggested tools such as the Balanced Scorecard and Tableau for effectively managing ports' environmental sustainability.

Several studies emphasize the importance of measuring a port's environmental performance. Puig et al. [7] evaluated the environmental performance of 97 European ports, showing widespread compliance with environmental standards. Castellano et al. [56] suggest that both environmental and economic performance should be assessed simultaneously. Stakeholder engagement is crucial in driving these efforts, pressuring port authorities to analyze environmental data and seek solutions [57]. Rodrigues et al. [51] categorized these indicators into water consumption, energy efficiency, and emissions, while Puig and Dabra [6] included air and sediment quality, noise, and biodiversity. Laxe et al. [58] used a Global Synthetic Index of Sustainability (GSIS) to measure environmental performance, finding that ports with higher cargo volumes generally had better sustainability scores.

The growing business volume in the port sector has underscored the need for integrating innovative technologies. Ports that implement such technologies, referred to as smart ports, not only enhance operational performance but also play a key role in promoting sustainability through the adoption of Environmental Management Systems (EMSs) [59]. Sustainable management practices are increasingly linked with smart technologies, offering ports a competitive edge in an industry where environmental performance has become a critical concern [60]. Praharsi et al. [48] developed a conceptual framework that connects smart and green port performance, providing a structured approach for ports seeking to align with these dual goals. The smart port concept, encompassing activities, technologies, and related software, has been widely researched, with Molavi et al. [61] proposing a Smart Port Index (SPI) featuring KPIs across four categories—operations, environment, energy, and safety—to quantify smart port development and assess strengths and weaknesses. Further studies have expanded on this concept [38]. Smart ports, by leveraging emerging technologies and innovations, can spearhead the transition toward more sustainable port management practices while simultaneously improving operational efficiency. By embedding smart technologies and sustainability goals into port concession agreements, ports can drive meaningful progress toward sustainability.

Sustainable port performance is often perceived as a barrier to development, with many port authorities viewing environmental monitoring programs as a hindrance to operations. However, Taljaard et al. [62] argue that implementing environmental strategies can change this perception. Custom regulations tailored to the specific features of each port are necessary to assess and improve environmental performance [63]. Lawer et al. [64] highlighted that while European ports prioritize climate change and air quality, West African ports focus on waste management and oil spills based on environmental priorities.

European ports have generally been more progressive in adopting sustainable practices, focusing on internal environmental management and stakeholder engagement [13]. Compliance with environmental regulations is often a key motivator for ports to implement greener practices [60]. Angelopoulos et al. [65] propose developing a global regulatory framework to address the challenges of implementing sustainability policies.

Stakeholder engagement also plays a critical role in enhancing port environmental performance. Studies by Argyriou et al. [66,67] and Ignaccolo et al. [68] stressed the importance of involving communities and stakeholders in decision-making processes. Similarly, Felicio et al. [15] pointed to the benefits of investing in local communities to meet sustainability goals. In the port sector, this involvement translates into participatory governance models, informed decision-making, collaborative approaches, and greater transparency. Effective stakeholder engagement enhances stakeholder satisfaction while ensuring that sustainability strategies align with regulatory requirements and community expectations, ultimately fostering long-term environmental and social benefits.

In the port-related literature, concession agreements are increasingly recognized as essential tools for implementing and monitoring environmental measures within port oper-

ations [16,18,19,22]. Traditionally, these agreements have prioritized economic objectives and operational efficiency. However, environmental sustainability is often not a primary focus for private operators, underscoring the need to integrate enforceable environmental clauses to ensure that sustainability standards are maintained throughout the concession period. A growing body of research highlights the importance of these clauses, with scholars advocating for their inclusion to align private sector activities with broader public environmental goals [17,22,69].

Despite this progress, the literature on this topic remains limited, emphasizing the need for more comprehensive analysis to fully understand the role of concession agreements in promoting environmental sustainability in ports. This paper adds to the existing discussion by shedding light on this largely underexplored area, hopefully stimulating further research and discussion on the role of concession agreements in advancing environmental sustainability within the port industry.

3. Materials and Methods

This paper employs a qualitative research approach to examine the integration of environmental sustainability into port concession agreements. The methodology draws upon an extensive review of the literature and a sample of available concession agreements and reference texts. By synthesizing academic discourse with empirical evidence, this paper contributes to the ongoing discussions on environmental sustainability in port operations and provides insights into developing a clear and comprehensive reference framework for future concession agreements.

This research began with a series of discussions with experts in the field of ports, both from academia and industry, who provided valuable insights regarding environmental considerations and the associated parameters and KPIs relevant to sustainability. This input helped the authors make an informed decision on overarching categories, as well as the parameters and KPIs under these categories that are most significant. A thorough literature review followed, exploring environmental challenges and performance issues associated with port operations and development. Through an extensive search of the Google Scholar database, relevant publications on environmental sustainability in ports and port concession agreements were identified and analyzed. This process verified and supplemented expert input, enabling the extraction of key insights from the existing literature and contributing to a deeper understanding of prevailing discussions and emerging trends in the field. The identified environmental parameters and KPIs were then systematically linked to relevant scholarly works, ensuring that academic perspectives were integrated into the analysis and allowing key conclusions from the literature to emerge. Despite differences in focus across the literature, resulting in a somewhat fragmented landscape, a synthesis of this work supports a comprehensive understanding of the topic. Ultimately, environmental parameters and KPIs are grouped in this paper into two broad categories:

- Environmental challenges and necessary actions: This category identifies major environmental issues that ports must address, along with the actions required to mitigate these challenges, thereby promoting sustainability in port activities.
- Concessionaire obligations and indicators: This category defines the responsibilities of concessionaires, extending beyond mere legal compliance to encourage advanced environmental practices. Each obligation is associated with KPIs to monitor performance in areas such as emissions reduction, energy use, resource efficiency, etc.

The methodology combines these two categories to create a comprehensive approach that integrates high-level environmental goals with practical, measurable actions applicable to future concession agreements. This structure facilitates the systematic incorporation of environmental sustainability into port concession agreements, aiming to improve port

operations and reduce environmental impact. Ensuring broad coverage of environmental parameters relevant to port operation and development, the methodology accounts for both direct and indirect impacts, offering a holistic understanding of environmental requirements. Guided by specific sustainability objectives and outcomes, this research follows a result-oriented approach designed to generate tangible results and drive meaningful change. These criteria collectively support a structured research process that effectively embeds environmental considerations into port concession agreements.

Additionally, the qualitative research methodology extended to an in-depth study of available concession agreements, as presented in Table 1. While expanding the sample size is necessary for a more comprehensive understanding, this material provides a solid foundation for examining the proposed hypotheses, drawing interesting preliminary conclusions, and validating insights drawn from the literature review. However, a certain limitation lies in the fact that, in most cases, such agreements are not publicly accessible, which restricts the scope of analysis to the available documents.

Table 1. Port concession agreements analyzed.

Port	Country	Date	Duration
Ehoala port	Madagascar	2006	30 years
Port of Cartagena	Colombia	2021	20 years
Port of Kerala	India	2015	40 years
Port of Wilmington	Usa	2018	50 years
Port of Mumbai	India	2021	50 years
Port of Bolivar	Ecuador	2016	50 years
Port of Timor	Indonesia	2016	30 years
Port of Puerto Plata	Dominican Republic	2018	30 years
Port of Goia Tauro	Italy	2019	30 years
Port of Piraeus I	Greece	2008	35 years
Port of Piraeus II	Greece	2016	35 years
Port of Thessaloniki	Greece	2018	33 years
Port of Igoumenitsa	Greece	2023	39 years

Source: authors, 2024.

The analysis was further enriched by examining available reference texts from organizations such as the World Bank and the International Bank for Reconstruction and Development [70,71], the United Nations [72], the United Nations Economic and Social Commission for Western Asia and the Islamic Development Bank [73], the European Bank for Reconstruction and Development [74], the European Union [75], and other bodies [76–78] which aim to standardize port concession agreements by integrating various requirements and addressing the sector's challenges (see Table 2). Although this sample is limited in scope, it offers preliminary insights into how environmental considerations are currently being incorporated into concession agreements, enabling comparative analysis against international frameworks and guidelines. These reference texts, while foundational, often lack concrete environmental provisions, underscoring the urgent need for a more robust framework.

Table 2. Templates and guidelines analyzed.

Publisher	Reference Texts	Publication Year
International Bank for Reconstruction and Development/The World Bank	Port Reform Toolkit [70]	2007
World Bank Group/World Bank	Sample Port Concession Agreement [71]	2009
European Union	Directive 2014/23/EU [75]	2014
United Nations—Economic and Social Commission for Asia and the Pacific (ESCAP)	Model Agreement Development of a Dry Port under PPP mode [72]	2016
SSATP Africa Transport Policy Program	Container Terminal Concession Guidelines [76]	2017
United States Agency for International Development	Port agreement templates [77]	2018
United Nations Economic and Social Commission for Western Asia and Islamic Development Bank	Public Private Partnership (PPP) for Ports Development and Operation [73]	2020
Indian Ministry of Shipping, R. T. & H.	Model Concession Agreement for Private Sector Projects in Major Ports [78]	2021
European Bank for Reconstruction and Development (EBRD)	Model heads of terms for seaport concession PPP agreement [74]	2024

Source: authors, 2024.

4. Results

4.1. Environmental Challenges

Environmental considerations vary across different port activities and terminals, reflecting the distinct nature of each operation and the diverse impacts they entail. Container terminals, passenger terminals, cruise terminals, cargo terminals handling bulk commodities like coal, ores, or grains, and LNG terminals all encounter their own set of environmental challenges. As ports increasingly diversify into new activities such as providing energy services or hosting offshore wind farms, environmental considerations expand to include issues such as habitat disturbance, marine pollution, and underwater noise. While certain issues such as air pollution, noise, degradation of the environment, and landscape change may be common across many, if not all, activities and terminals, the specific causes and manifestations of these challenges differ based on the specificities of each operation. Consequently, environmental considerations and relevant provisions to be integrated into concession agreements must be tailored accordingly in order to adequately address the specific environmental risks and impacts associated with each port activity and terminal.

The analysis of the relevant literature reveals that ports face a broad spectrum of environmental challenges, each of which presents unique risks and impacts. Although some issues may attract more immediate attention due to regulatory pressures, health concerns, or operational priorities, no single environmental challenge can be considered more important than another, and none can be conclusively prioritized over others. The complexity of port operations and development necessitates a comprehensive, multifaceted approach to address these challenges, ensuring consideration of key priorities such as air

quality, water conservation, soil health, biodiversity preservation, noise and light pollution, energy efficiency, waste management, climate adaptation, and sustainable development, tailored to the specific circumstances and needs of each case.

4.1.1. Air Quality

The literature highlights the substantial contribution of ports to the release of harmful pollutants like carbon dioxide (CO_2), nitrogen oxides (NO_x), and sulfur oxides (SO_x) into the atmosphere [10,64,79]. These emissions negatively impact local air quality, contributing to both regional health problems and global climate change. Ports have increasingly turned to cleaner technologies and alternative fuels to mitigate these effects. In addition, many ports are incentivizing environmentally friendly shipping practices through initiatives aimed at reducing emissions from vessels [80,81]. While air quality issues often receive urgent attention, they form just one element of a broader environmental management framework.

4.1.2. Water Conservation

Water conservation is another pressing challenge for ports, particularly in managing ballast water discharge and controlling water pollution from spills or dredging activities. Ballast water has been a major contributor to the introduction of invasive species, which can severely disrupt local ecosystems [80]. Furthermore, dredging, an essential activity for maintaining port navigation channels, can disturb sediments and release pollutants trapped in the seabed, compromising water quality [10,82]. The review underscores that while many ports are adopting advanced ballast water treatment systems and sustainable dredging practices, smaller ports may face difficulties in implementing these due to resource constraints.

4.1.3. Soil Conservation

Ports contribute to soil contamination primarily through industrial activities, waste disposal, and expansion projects. According to the literature, toxic waste and construction debris from dredging operations have significant negative impacts on soil health [5,23]. Efficient land use strategies, combined with measures to prevent soil contamination, are critical for minimizing the environmental footprint of port operations. Ports must prioritize land management practices that enhance productivity while mitigating soil degradation.

4.1.4. Noise Pollution

Ports, particularly those located near urban areas, are significant sources of noise pollution [23], which can affect both the local population and port workers. Cargo handling equipment, vessel movements, and other operational activities contribute to a constant noise load. The literature indicates that ports are increasingly adopting measures like sound barriers and operational curfews to mitigate these impacts, though balancing noise reduction with operational efficiency remains a challenge [5,64]. This issue, though less visible than air or water pollution, has important implications for port–community relations and overall sustainability.

4.1.5. Light Pollution

Light pollution, often overlooked, can also have detrimental effects on ecosystems, especially for ports located near coastal habitats. The excessive use of artificial lighting during night operations interferes with the natural behaviors of wildlife, particularly nocturnal species [5,82]. As awareness of this issue grows, some ports have adopted smart lighting systems that reduce unnecessary illumination while ensuring safety and

maintaining operational efficiency. This emerging challenge, although subtle, adds another layer of complexity to port environmental management.

4.1.6. Biodiversity Conservation

Port operations pose serious risks to biodiversity, particularly in regions near ecologically sensitive areas. Habitat destruction due to port expansion and the introduction of invasive species through ballast water discharge are leading concerns [80]. The literature emphasizes the importance of ports collaborating with environmental authorities to implement biodiversity conservation programs, such as habitat restoration and the integration of eco-friendly infrastructure [83]. Biodiversity preservation is increasingly becoming a focal point for ports aiming to mitigate their ecological impact while balancing operational growth.

4.1.7. Energy Efficiency and Renewable Energy Integration

Energy efficiency has emerged as a critical concern in port operations, given the high energy demands of cargo handling, lighting, and other activities. The literature underscores the role of ports in reducing energy consumption by upgrading to more efficient equipment and processes [5]. In parallel, renewable energy integration is gaining momentum as ports strive to decarbonize their operations by incorporating solar, wind, and other sustainable energy sources [81]. By embracing energy efficiency and renewable energy, ports not only improve their environmental performance but also enhance their economic competitiveness by reducing operational costs in the long term [84].

4.1.8. Waste Management

Ports generate considerable waste, including hazardous materials and industrial by-products, necessitating effective waste management systems to mitigate environmental contamination. The literature indicates that many ports are adopting waste management practices that focus on recycling, reducing hazardous waste, and ensuring proper disposal in line with environmental regulations [85–87]. Effective waste management is crucial for minimizing the environmental footprint of port operations, yet it remains a significant challenge, especially for smaller or resource-constrained ports.

4.1.9. Climate Change

Climate change is one of the most significant long-term threats to port infrastructure and operations. Rising sea levels, more frequent extreme weather events, and shifting climate patterns pose existential risks to port infrastructure and the surrounding coastal ecosystems [61,81]. Ports are increasingly focusing on developing climate-resilient infrastructure, adopting sustainable planning practices, and incorporating climate change considerations into their long-term strategies. As essential stakeholders in the global supply chain, ports also play a vital role in contributing to the decarbonization of maritime transport and reducing global greenhouse gas emissions.

4.1.10. Sustainable Development

Finally, sustainable development emerges as a central theme in the literature, with ports facing increasing pressure to integrate economic, social, and environmental dimensions into their operational frameworks. Ports are uniquely positioned at the intersection of urban, industrial, and ecological systems, and their activities have wide-reaching implications for local communities and economies. The literature emphasizes that sustainability in ports goes beyond environmental considerations, incorporating issues such as workforce well-being, local economic development, and urban integration. Incorporating sustainability goals into concession agreements, establishing KPIs, and engaging stakeholders in

long-term planning are becoming common practices as ports align themselves with global sustainable development goals [10,81].

4.1.11. Shifting Environmental Priorities

The ESPO Environmental Report EcoPortsinSights 2024 [1] sheds light on the top environmental challenges that European ports have faced from 1996 to 2023, offering a comprehensive overview of the shifting priorities in this sector (Figure 1).

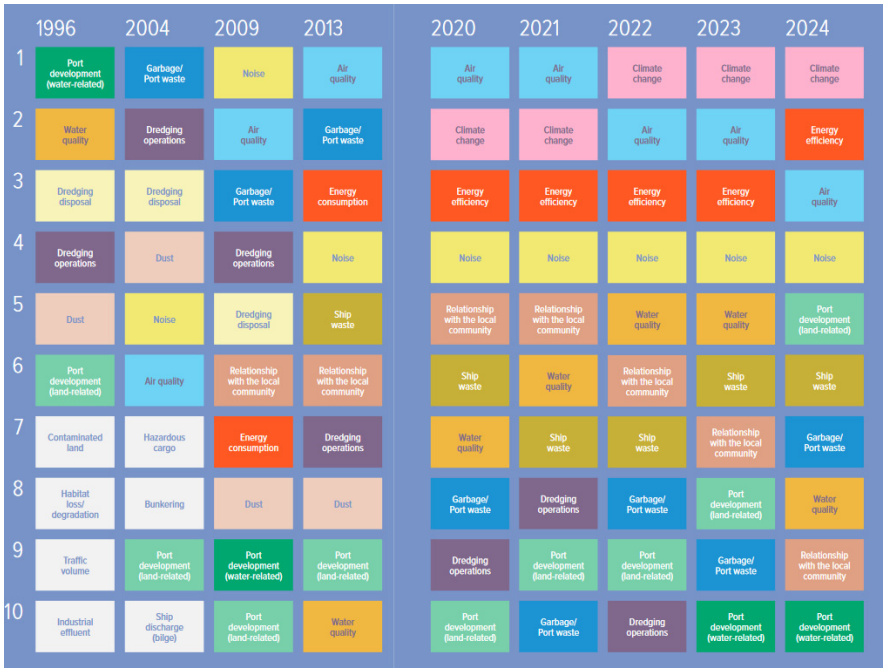

Figure 1. Top 10 environmental priorities of the European port authorities. Source: ESPO, Environmental Report EcoPortsinSights 2024, 2024 [1].

While challenges such as climate change, air quality, energy efficiency, and noise pollution are increasingly gaining prominence, it is important to acknowledge that environmental priorities vary significantly from port to port, from terminal to terminal, and depending on the specific activities taking place within each port. These variations are driven by factors such as location, the type of cargo handled, the scale of operations, and the surrounding geographic and socio-political contexts. Moreover, the challenges identified in the report, while focused on European ports, are indicative of broader global port challenges. Ports around the world are confronting similar environmental concerns, though the intensity and specific nature of these issues may vary. For instance, some ports might prioritize water pollution control due to their proximity to vulnerable ecosystems, while others may focus on reducing emissions from heavy industrial activities.

In essence, while the ESPO Environmental Report provides a valuable snapshot of the environmental landscape in Europe, it also highlights broader trends that are relevant for ports worldwide, emphasizing the need for tailored sustainability strategies that align with both local circumstances and global environmental goals.

4.2. Environmental Parameters and KPIs

This section focuses on the key environmental parameters that ports must address, along with specific KPIs to measure their progress. The tables presented in this section are structured into two overarching categories that guide the identification of challenges and establish measurable actions:

- Environmental challenges and considerations/Necessary actions: This category highlights the key environmental challenges that ports face today. From air quality management to biodiversity conservation, energy and waste management, climate change mitigation and adaptation or resilience, etc., it outlines the necessary steps ports should take to mitigate negative effects on the environment. These actions aim to reduce pollution, conserve resources, and promote sustainable operations within the port industry. By addressing these key areas, ports can significantly minimize their environmental footprint and contribute to wider sustainability efforts.
- Obligations for concessionaires/Indicators: This category establishes specific responsibilities and contractual obligations for port concessionaires, aimed at fostering the integration of advanced environmental standards and practices while driving investments in green infrastructure. These obligations surpass mere regulatory compliance, imposing the adoption of innovative environmental measures and sustainable operational methods that go beyond basic legal requirements. Each obligation is linked to KPIs that track and assess the effectiveness of implemented actions. These KPIs ensure consistent monitoring of progress and hold concessionaires accountable for their environmental contributions, reinforcing their role in achieving long-term sustainability goals.

4.2.1. Environmental Challenges and Considerations/Necessary Actions

Tables 3–6 provide a structured and detailed overview of "environmental challenges and considerations/necessary actions" within the port sector. The first column identifies the environmental pillar under focus, while the second and third columns outline key challenges and associated considerations alongside proposed actions or strategies. The final column presents indicative references, derived from an extensive literature review and analysis. Collectively, these tables serve as an evidence-based framework for addressing critical environmental issues and advancing sustainability in port operations and development.

The "pollution and conservation" category, as presented in Table 3, offers a structured and comprehensive framework for minimizing the environmental impacts of ports. It highlights the need for a balanced approach, where ports must integrate both operational efficiency and strategic development on the one hand and environmental responsibility on the other. By adopting various pollution control measures, ports can also contribute to broader conservation efforts, ensuring sustainable practices across multiple environmental dimensions. Each action listed in this category is both practical and essential for achieving long-term environmental goals, all while adhering to regulatory obligations and beyond.

Table 3. Pollution and conservation (key considerations).

Pollution and Conservation			
Environmental Pillar	**Key Considerations**	**Description**	**Indicative References**
Air quality management	Emission reduction	Implement strategies to reduce air emissions from port operations, including the use of cleaner fuels and technologies.	[8,10,24,36,42,47,51,60,79,88,89]
	Air quality monitoring	Regularly monitor air quality to ensure compliance with environmental standards and identify areas for improvement.	[6,9,83,88]
Water conservation	Water use efficiency	Adopt measures to conserve water and use it efficiently within port operations.	[51]
	Pollution prevention	Implement strategies to prevent water pollution from port activities, including stormwater management.	[6,49,83]

Table 3. *Cont.*

Pollution and Conservation			
Environmental Pillar	**Key Considerations**	**Description**	**Indicative References**
Soil conservation	Soil erosion prevention	Implement measures to prevent soil erosion from port activities, including proper land use and vegetation cover.	[3,8,42]
	Contaminated soil management	Develop strategies for managing and remediating contaminated soil to prevent environmental and health hazards.	[3]
	Sustainable land use practices	Promote sustainable land use practices to maintain soil health and productivity.	[9]
Noise pollution control	Noise mitigation measures	Implement measures to reduce noise pollution from port activities, such as sound barriers and operational changes.	[8,42,83]
	Noise monitoring	Regularly monitor noise levels to ensure compliance with regulations and minimize impact on nearby communities.	[6]
Odor emissions	Odor pollution mitigation	Implement measures to reduce odor by activities like waste handling, handling and storage of certain bulk materials, as well as emissions from vessels and land-based operations.	[4,5]
	Odor pollution monitoring	Constantly monitor and timely detect odor emissions.	[5]
Light pollution control	Light pollution mitigation	Implement measures to reduce light pollution during night operations, such as using shielded lighting and minimizing unnecessary lighting.	[5]
	Light pollution monitoring	Regularly monitor light pollution levels to ensure compliance with environmental standards and minimize impact on nearby areas.	[90]
Biodiversity conservation	Marine habitat preservation	Protect marine habitats and ecosystems affected by port activities.	[28,47,62]
	Wildlife conservation	Safeguard local wildlife, including implementing measures to protect species and their habitats.	[4]

Source: authors, 2024.

As shown in Table 4, the "management initiatives" category under "environmental challenges and considerations/necessary actions" emphasizes the need for strategic environmental management to improve sustainability in port operations and development. This category highlights energy efficiency, renewable energy integration, waste management, and environmental impact assessments as critical areas requiring attention. Each initiative encourages ports to adopt sustainable practices that not only enhance operational performance but also reduce their environmental footprint. Each management initiative outlined in this category emphasizes proactive action and long-term environmental stewardship. These measures not only fulfill regulatory obligations but also ensure that ports contribute positively to sustainability.

Table 4. Management initiatives (key considerations).

Management Initiatives			
Environmental Pillar	**Key Considerations**	**Description**	**Indicative References**
Energy efficiency	Energy-efficient practices	Implement energy-efficient practices and technologies to optimize port operations and reduce energy consumption.	[3,6,47,48,84]
	Rationalization/reduction in energy use	Adopt strategies to rationalize and reduce overall energy use in port operations.	[3,24,58]
	Energy audits and monitoring	Conduct regular energy audits and monitor energy usage to identify opportunities for improvement.	[51,63]

Table 4. *Cont.*

Management Initiatives			
Environmental Pillar	**Key Considerations**	**Description**	**Indicative References**
Renewable energy integration	Renewable energy sources	Promote the adoption of renewable energy sources such as solar, wind, and bioenergy.	[50]
	Green infrastructure investment	Invest in eco-friendly infrastructure projects, including electrification of port equipment and shore power facilities for vessels.	[9]
Waste management	Sustainable waste practices	Implement sustainable waste management practices, including reduction, reuse, and recycling.	[6,9,60,86]
	Hazardous materials handling	Ensure proper handling, storage, and disposal of hazardous materials to prevent environmental contamination.	[58]
	Circular economy principles	Promote the adoption of circular economy principles to minimize waste and enhance resource efficiency.	[59,89]
	Waste reduction and monitoring	Implement strategies to significantly reduce waste generation in port activities and develop procedures to monitor the amount of waste generated in the port area.	[6,9,41]
Environmental impact assessment	Comprehensive impact assessments	Conduct thorough environmental impact assessments (EIAs) to evaluate potential impacts of port activities and development projects, Implement Environmental Management Systems (EMSs).	[7,23,42,91,92]
	Mitigation measures	Identify and implement measures to mitigate identified negative environmental impacts.	[23,31]
Investment in green/sustainable infrastructure	Green investments for sustainable operation and development	Invest in environmentally friendly, energy-efficient, and resilient infrastructure. Promote the electrification of port equipment. Implement measures for the on-shore power supply. Integrate sustainable materials and methods in construction projects.	[63,93,94]

Source: authors, 2024.

As shown in Table 5, the "sustainable development and climate change adaptation" category under "environmental challenges and considerations/necessary actions" focuses on fostering the sustainability of ports and enhancing their resilience to climate change impacts. Through sustainable infrastructure, green building standards, and proactive adaptation strategies, ports can achieve both immediate and mid- and long-term environmental and sustainability goals.

Table 5. Sustainable development and climate change adaptation (key considerations).

Sustainable Development and Climate Change Adaptation			
Environmental Pillar	**Key Considerations**	**Description**	**Indicative References**
Sustainable development	Sustainable infrastructure	Develop and maintain infrastructure that supports sustainable development goals and minimizes environmental impact.	[23,89,95,96]
	Green building standards	Apply green building standards to port facilities to enhance sustainability and reduce environmental footprint.	[89,95,97]
Climate change adaptation	Resilience planning	Develop and implement plans to enhance the resilience of port infrastructure and operations to climate change impacts.	[61,93]
	Carbon footprint reduction	Implement strategies to reduce the carbon footprint of port activities, including energy efficiency and renewable energy initiatives.	[9,50,83,98]

Source: authors, 2024.

As shown in Table 6, the "other considerations" category under "environmental challenges and considerations/necessary actions" highlights essential areas that go beyond direct operational impacts but play a crucial role in fostering a sustainable and responsible approach within port operations. This category emphasizes the importance of community engagement, environmental education, monitoring and reporting, and collaboration for collective sustainability improvements.

Table 6. Other considerations (key considerations).

Other Considerations			
Environmental Pillar	**Key Considerations**	**Description**	**Indicative References**
Community engagement	Stakeholder involvement	Engage with local communities and stakeholders to address environmental concerns and foster collaborative solutions.	[9,11,15,35,60,83,99] [27,47,49,66,67]
	Transparency and reporting	Ensure transparency in environmental performance and regularly report on sustainability initiatives and outcomes.	[50,95,97]
Environmental education	Training and awareness programs	Implement training and awareness programs for port staff and stakeholders on environmental best practices and sustainability.	[35,55,83,95,97,99]
	Research and development	Invest in research and development to innovate and implement new environmental technologies and practices.	[9,55]
Monitoring and reporting	Sustainability performance tracking	Provisions for monitoring and reporting on sustainability performance, tracking progress, and compliance with sustainability goals throughout the concession period.	[95,97,100]
Collaboration and knowledge sharing	Best practice sharing	Ports collaborating and sharing best practices for sustainable operations, fostering collective improvement of sustainability standards in the industry.	[95–97]

Source: authors, 2024.

4.2.2. Obligations for Concessionaires/Indicators

Tables 7–10 present the results for the category "obligations for concessionaires/indicators". These tables focus on aligning concessionaire responsibilities with environmental goals by outlining key obligations for integrating sustainability into port operations and development. Each table is organized to address specific environmental pillars, with the second column detailing the associated obligations for concessionaires. The third column identifies potential indicators for tracking and evaluating the implementation and effectiveness of these obligations. The final column provides indicative references, based on thorough literature research and analysis, to support the integration of these practices.

As shown in Table 7, the "pollution and conservation" category under the obligations for concessionaires and indicators provides a structured framework for compliance and monitoring, ensuring that concessionaires contribute to minimizing the environmental impact of port operations. This table specifies the actions that concessionaires must take to meet environmental goals and establishes measurable indicators to track their performance in reducing pollution and promoting conservation. Each environmental pillar outlines obligations that are enforceable and measurable, ensuring accountability in maintaining sustainability practices.

Table 7. Pollution and conservation (obligations and KPIs).

Pollution and Conservation			
Environmental Pillar	**Obligations for Concessionaire**	**Possible Indicators**	**Indicative References**
Air quality management	• Adopt low-sulfur fuels and install emission control technologies. • Conduct regular air quality monitoring.	Reduction in NO_x, SO_x, PM emissions	[9,10,36,47,60,79]
	Install and maintain air quality monitoring stations. • Submit emissions reports to regulatory agencies.	Compliance with air quality standards, emission levels	[6,10,51,79]
Water conservation	• Implement water-saving technologies (e.g., low-flow fixtures). • Monitor and report water usage.	Water consumption rates, efficiency improvements	[6,9,51]
	• Develop stormwater management plans. • Treat and control runoff before discharge.	Water quality assessments, pollutant levels in runoff	[58]
Soil conservation	• Use erosion control practices (e.g., vegetative cover). • Monitor erosion rates regularly.	Soil erosion rates, effectiveness of erosion control measures	[3]
	• Conduct soil testing and remediate contaminated areas. • Monitor soil quality indicators.	Contaminant levels, success of remediation efforts	[3]
Noise pollution control	• Install noise barriers and use quiet technologies. • Conduct noise surveys and assessments.	Noise levels, community noise exposure	[6,28]
	• Implement noise reduction plans. • Ensure compliance with noise regulations.	Compliance with noise standards, noise impact assessments	[28]
Light pollution control	• Use shielded lighting and reduce unnecessary nighttime lighting. • Monitor light intensity levels.	Light intensity levels, light spillage monitoring	[63]
	• Implement lighting management plans. • Comply with light pollution regulations.	Compliance with light pollution standards, light exposure	[63]
Odor emissions	• Develop strategies and introduce measures to effectively reduce odor emissions by port activities and operations. • Implement robust and effective monitoring and detection systems for odor pollution. • Establish odor critical thresholds for timely response.	Frequency of odor events, time for addressing and mitigating odor-related complaints from local communities, odor monitoring systems implemented	[101]
Biodiversity conservation	• Implement habitat restoration projects. • Monitor biodiversity indicators regularly.	Species diversity indices, habitat health assessments	[6]
	• Establish conservation zones and wildlife protection measures. • Participate in biodiversity surveys.	Wildlife population trends, habitat condition assessments	[4]

Source: authors, 2024.

As shown in Table 8, the "obligations for concessionaires/indicators" category under "management initiatives" outlines specific responsibilities and measurable indicators that ports must adhere to in order to enhance their sustainability practices and minimize

environmental impacts. This table emphasizes the critical role that measurable obligations and indicators play in ensuring that ports are actively engaged in sustainable practices. By adhering to these obligations, ports can significantly reduce their environmental impact while contributing to broader sustainability goals. This framework is designed to ensure compliance with environmental regulations while fostering continuous improvement through accountability.

Table 8. Management initiatives (obligations and KPIs).

Management Initiatives			
Environmental Pillar	**Obligations for Concessionaire**	**Possible Indicators**	**Indicative References**
Energy efficiency	• Conduct energy audits and implement efficiency measures. • Monitor and report energy consumption.	Reduction in energy consumption, energy efficiency ratings	[24,50,51,59,97]
	• Set energy reduction targets and optimize equipment usage. • Invest in energy-saving technologies.	Achievement of energy reduction goals, energy usage trends	[83]
Renewable energy integration	• Install solar panels and wind turbines for renewable energy generation. • Integrate renewable energy systems.	Proportion of renewable energy, renewable energy capacity	[83]
	• Develop green infrastructure and support sustainable building practices.	Investments in renewable infrastructure, green projects	[83,89]
Waste management	• Develop waste reduction plans and increase recycling efforts. • Develop waste monitoring procedures, mechanisms, and tools. • Implement waste collection strategies. • Comply with hazardous waste disposal regulations.	Waste diversion rates, recycling rates	[6,9,58,86]
	• Implement spill prevention and response plans. • Conduct hazardous waste audits.	Compliance with hazardous waste regulations, spill incidents	[58]
	• Explore opportunities for material reuse and lifecycle assessments. • Integrate circular economy practices.	Circular economy initiatives, waste lifecycle assessments	[59,89]
Environmental impact assessment	• Assess environmental risks and propose mitigation measures. • Submit impact assessment reports.	Environmental impact assessment reports, mitigation measures	[23]
Investment in green/sustainable infrastructure	• Invest in electrification of port equipment and shore power facilities. • Promote use of alternative fuels.	Electrification projects, alternative fuel adoption	[89]

Source: authors, 2024.

As demonstrated in Table 9, the "obligations for concessionaires/indicators" category under "sustainable development and climate change adaptation" delineates specific responsibilities and measurable indicators that ports must follow to foster sustainable development and adapt to the effects of climate change. This framework not only highlights the significance of these obligations but also reinforces the necessity for ports to proactively engage in sustainability initiatives.

By adhering to these responsibilities, ports can enhance their resilience while effectively minimizing their environmental footprint. Such a structured approach ensures that they are well equipped to tackle current environmental challenges and contribute to long-term sustainability goals.

As shown in Table 10, the "obligations for concessionaires/indicators category" under "other considerations" outlines specific responsibilities and measurable indicators that ports must adhere to in order to enhance community engagement, promote environmental education, and facilitate collaboration within the industry. This framework ensures that ports actively contribute to their local communities and prioritize sustainable practices.

Table 9. Sustainable development and climate change adaptation (obligations and KPIs).

Sustainable Development and Climate Change Adaptation			
Environmental Pillar	**Obligations for Concessionaire**	**Possible Indicators**	**Indicative References**
Sustainable development	• Use green building standards and sustainable construction practices. • Monitor environmental impacts of projects.	Sustainability certifications, green ratings	[23,89]
Climate change adaptation	• Develop climate adaptation plans and strategies. • Implement measures to reduce greenhouse gas emissions.	Resilience planning, emission reductions	[98]

Source: authors, 2024.

Table 10. Other considerations (obligations and KPIs).

Other Considerations			
Environmental Pillar	**Obligations for Concessionaire**	**Possible Indicators**	**Indicative References**
Community engagement	• Participate in community outreach programs and address environmental concerns.	Community feedback, stakeholder engagement	[14]
Environmental education	• Educate employees and stakeholders on environmental practices and policies.	Training participation rates, awareness levels	[59]
	• Innovate new technologies and solutions for environmental improvement.	Research outputs, technology adoption	[48,59]
Monitoring and reporting	• Establish a comprehensive monitoring system and report on environmental metrics.	Sustainability performance reports	[23,28,51,102]
Collaboration and knowledge sharing	• Collaborate with industry peers and share knowledge on sustainable initiatives.	Participation in industry initiatives	[59,102]

Source: authors, 2024.

4.3. Environmental Provisions in Existing Concession Agreements and Reference Texts

As ports play a critical role in economic activity worldwide and their business is constantly increasing, their environmental impact has come under greater scrutiny, further emphasizing the importance of integrating environmental sustainability into concession agreements. In response to the growing environmental pressures, as described above, and the global shift toward sustainable development, there is increasing recognition of the need for more detailed environmental provisions in CAs. From the study of the available concession agreements and reference texts scrutinized for the purposes of this research, environmental clauses in existing CAs remain underdeveloped compared to economic and financial terms, reflecting a historical focus on profitability and operational efficiency. While economic parameters are often meticulously detailed, environmental considerations tend to be treated in a more general and non-specific manner. This disparity highlights a significant gap in incorporating sustainability into port management and development. Despite the prominence of global sustainability frameworks, clear and binding environmental standards within CAs are often lacking, with many agreements offering vague or minimal references to environmental protection. Existing environmental obligations typically refer to prevailing legislation without extending beyond basic compliance requirements. This observed difference highlights potential deficiencies in the depth of integration and commitment to sustainable practices within port concession agreements. The limited incorporation of environmental provisions stems from the complex nature of sustainability in the port sector, where diverse stakeholders with differing interests influence agreement

terms. Furthermore, environmental parameters can be difficult to quantify, making it challenging to embed them in concrete legal clauses.

However, several model agreements and guidelines have emerged in recent years, offering frameworks to enhance environmental accountability in CAs (see Section 3). They include provisions touching upon environmental aspects, although they often lack specificity. These documents encourage port operators to consider parameters such as pollution reduction, resource conservation, the use of renewable energy, and waste management, but the language used is often broad, resulting in limited enforceability. Similarly, the European Union's Directive 2014/23/EU [75] promotes the inclusion of environmental criteria in CAs, yet the practical application of such clauses varies significantly depending on the different regulatory frameworks. This lack of specificity underscores the need for the development of an analytical framework for including environmental parameters in CAs. Such a framework could set, for instance, clear targets for emissions reductions, energy efficiency, and waste management, along with robust monitoring systems to ensure compliance. The inclusion of specific, measurable environmental commitments tied to KPIs would ensure that concessionaires are held accountable for their environmental footprint.

Overall, the key findings of this paper as presented in Section 4 highlight the importance of incorporating environmental considerations into both port operations and development strategies through concession agreements. This paper not only emphasizes the integral role of concessionaires in promoting environmental stewardship within port operations and development activities but also provides a comprehensive framework to guide their environmental initiatives. Through adherence to the obligations outlined in concession agreements, concessionaires can contribute to the advancement of sustainable practices, fostering environmental conservation and resilience within the port industry. In terms of port development, there is a need to encourage a transformative process that steers the port sector toward a more sustainable trajectory. At a strategic level, port concessions should drive decisions and master plans aimed at reducing the port's environmental footprint in the medium and long term and addressing key environmental issues through considerable changes in port organization, business models, and operations. Stakeholders' collaboration is also vital for improving environmental performance in the sector and ensuring sustainable development practices. Moreover, moving forward, the development of standardized frameworks or model agreements that include environmental sustainability at the core of port operations and development is essential. Such provisions will help ports align with global environmental objectives, such as the Sustainable Development Goals, the Paris Agreement [103], or the European Green Deal [104], while fostering a culture of sustainability within the industry. Furthermore, this approach will enhance the relationship between ports and their cities by increasing the value provided to relevant stakeholders. Lastly, given the evolving nature of environmental regulations, provisions should allow port authorities and states to renegotiate outdated environmental clauses, ensuring that ports remain compliant with current environmental standards.

5. Discussion

5.1. Sustainability and Trends in the Port Industry

The port sector is undergoing a significant transformation toward sustainability, driven by increasing environmental pressures, societal expectations, evolving regulatory frameworks, and a growing recognition that sustainable practices enhance both environmental performance and economic resilience. This shift necessitates a holistic rethinking of port governance, operations, and development. Decisions made by port operators, regulators, policymakers, and concessionaires are progressively prioritizing the environmental dimension. Industry trends reflect a growing acknowledgment that ports must reduce

their environmental impact, modernize their practices, and align with global sustainability targets [32,83].

Despite this momentum, the integration of environmental standards into port concession agreements remains an evolving trend. While full Environmental, Social, and Governance (ESG) frameworks have yet to be widely adopted, the environmental pillar is gaining prominence. Industry developments indicate a growing emphasis on balancing economic growth with environmental responsibility, driving ports to implement advanced sustainability strategies. These changes create both new opportunities and obligations for all stakeholders [105–108]. Furthermore, technological advancements—including automation, digitalization, and big data—are playing a crucial role in supporting this transition, particularly in environmental monitoring and operational efficiency. The smart port concept is expected to become a standard in the near future, integrating various tools and technologies to facilitate the achievement of environmental targets more effectively [48,52,59,61]. At the same time, ensuring port security and operational resilience is becoming an essential component of sustainable port management, as recent studies highlight the interconnection between sustainability and security challenges, particularly in addressing risks related to safety, cyber threats, and operational harmony in ports [109].

For regulators and policymakers, sustainability mandates are leading to stricter environmental standards while encouraging a green transition. Ports are increasingly recognized as key contributors to both local and global sustainability efforts, prompting authorities to require concession agreements with clear environmental parameters. Concessionaires, as essential stakeholders, play a pivotal role in advancing the environmental sustainability of ports [17]. Although the environmental pillar of sustainability is not yet fully integrated into port concession agreements, future agreements will likely place greater emphasis on environmental requirements, mandating clear, measurable objectives to foster accountability and transparency. Concessionaires' active involvement in these strategies is crucial for the overall success of sustainability initiatives in ports, ensuring that environmental standards are not only met but continuously improved upon.

In essence, future trends in the port industry will encompass a comprehensive shift toward environmental sustainability. The port industry must reimagine its business model, transitioning from growth-driven development to an integrated approach that holistically considers environmental sustainability, industry transformation, and stakeholder engagement.

5.2. A Reflection on Theory and Practice

In recent years, there has been a noticeable upward trend in scientific research and academic discussions regarding the environmental aspects of port operations and development. This trend reflects the increasing environmental pressures caused by the port industry as ports intensify, diversify, and expand their activities. It also highlights a growing awareness of the environmental challenges and threats faced by society and local communities. The sustainability paradigm has strengthened this trend, creating significant momentum to integrate environmental concerns and sustainability into the strategic planning, management, and daily operations of ports and the broader port industry, as well as into port governance. Port authorities, terminal operators, and other stakeholders are increasingly recognizing environmental sustainability as a critical element of their activities, striving to balance competing objectives. This balance not only aims to improve the environmental footprint and foster more harmonious relationships with local communities, but also to ensure more rational operations and high-quality services that yield multiple benefits, including business improvements and profitability.

Despite this positive trend, port governance has often lagged behind expectations, leaving significant opportunities for port authorities and public policymakers to further embed environmental targets in their strategic choices and everyday decisions. Concession agreements can play a critical role in driving this transformation, serving as tools to modernize the port industry in various ways [16], particularly by advancing environmental sustainability. Port authorities and/or state governments hold the authority to negotiate and impose advanced environmental obligations on concessionaires. However, this power is not absolute, as various limitations can make it challenging to push for ambitious sustainability clauses [22].

Concession agreements must reflect market realities and be aligned with them, meaning only clauses that are acceptable to concessionaires can be included. This often results in pressure to minimize obligations, with compliance with existing environmental legislation typically serving as the compromise. While this represents the minimum standard, it would apply regardless. The real added value lies in going beyond current legislation to negotiate a higher level of sustainability. Given the pivotal role of concession agreements in the modern port industry, expectations for them are high. As the need to advance sustainability becomes more urgent, should these agreements continue to fall short of delivering adequate solutions, stricter environmental legislation and regulatory approaches may become necessary.

The environmental parameters, variables, and KPIs identified through the review of the relevant literature, port concession agreements, and reference texts systematically categorized in this paper contribute both to theoretical discourse and practical advancement in the field. Simultaneously, they provide a robust foundation for developing tailor-made concession agreements to meet the specific needs of the parties involved. However, among the numerous variables and KPIs discussed in Section 4, only a select few can realistically be applied to port concession agreements, based on their anticipated impact, practicality, and industry acceptance. While environmental considerations are linked to specific parameters, variables, and indicators, different operational needs require distinct metrics, making it both challenging and potentially risky to narrow down choices. A selection process is more than a technical decision; it forms part of a broader governance issue, where the preference for certain parameters or KPIs over others can significantly influence outcomes.

5.3. The Governance Issue

Incorporating environmental considerations into concession agreements presents a critical governance challenge within the port industry [19]. Port authorities and states play a central role in shaping concession agreements, also providing an opportunity to establish a comprehensive framework that prioritizes environmental performance and sustainability [110]. By negotiating terms with potential concessionaires, authorities can ensure that environmental objectives are given equal weight alongside economic considerations, fostering a more balanced relationship between these competing interests.

With regard to environmental sustainability, port authorities and/or governments have three alternatives when deciding on a port concession agreement, each representing varying levels of ambition and offering different paths to address environmental concerns. They have the option to perform the following:

- Include in concession agreements clear and concrete terms that aim for enhanced environmental protection and the integration of sustainable development into the operation and development of ports. This ensures that the environment and sustainability become core considerations for interested parties when expressing their interest in a concession and submitting their offer.

- Outline only a general framework of increased environmental protection, inviting potential bidders to express their interest and submit their bids in order to evaluate their offer and environmental commitment in the context of the intended investment in the hope of a race to the top, while the final formulation of these conditions will possibly also be the subject of the final negotiation process.
- Adhere to the level of environmental protection guaranteed by existing legislation, considering that basic protection is ensured and that there is no need for additional requirements, possibly hoping at the same time that the concessionaire will pursue higher environmental standards, reacting positively to market pressures, the paradigm of sustainable development, local community demands, and the fear of tightening environmental legislation.

This is a complex governance issue, where port authorities and/or governments, in shaping their choices, need to perform the following:

- Define the desired level of environmental protection in relation to port activities and development.
- Weigh the importance of environmental protection and the promotion of sustainable development against other objectives in the context of the intended concession.
- Identify and prioritize both key and secondary goals within the concession framework, but also select the appropriate means to achieve these goals and translate them into concrete terms, as well as specific and measurable indicators.
- Negotiate and finalize these terms with the prospective concessionaire, and subsequently ensure the proper implementation and monitoring of the concession agreement, making necessary adjustments and corrections along the way.

Each of the aforementioned points presents distinct challenges, and the choices involved are complex and multifaceted. The answers may vary depending on the perspectives of the stakeholders [20], the unique characteristics of each case, and the prevailing circumstances. Nevertheless, it is reasonable to expect that any port concession should align with the evolving demands of the sustainable development paradigm. Furthermore, the typically long duration of concession agreements—often spanning several decades—necessitates terms that not only address the conditions at the time of negotiation but are also forward-looking enough to accommodate future challenges. This is especially important given the rapidly increasing pressures and the continuously changing realities that ports and local communities will face in the years to come.

Of course, enhancing environmental sustainability through additional clauses in port concession agreements, beyond existing regulations, also raises concerns about impacting port competitiveness, potentially disadvantaging concessionaires, particularly in markets where ports compete for the same market share and clientele. Such measures may increase demand for a level playing field across the port sector. However, environmental sustainability is an urgent, collective priority that should not be viewed solely through a competitive lens among enterprises or port authorities. At the same time, market dynamics and realities must be acknowledged. Achieving sustainability requires a balanced approach, integrating economic, social, and environmental objectives rather than prioritizing one over the others. Effective governance is essential in this context: it involves setting clear goals and priorities, addressing challenges and finding adequate solutions, accommodating diverse interests, making thoughtful compromises at the highest level, and seeking consensus wherever possible.

Finally, as highlighted by Notteboom and Lam, the integration of environmental sustainability into concession agreements can only achieve its full potential when supported by a comprehensive, chain-wide environmental strategy encompassing ships, ports, terminals, warehouses, and other critical logistics components [22]. This perspective underscores a

broader governance challenge, positioning environmental sustainability in ports within a much wider operational and strategic context.

6. Conclusions

This paper highlights the urgent need for ports to adopt a comprehensive and forward-thinking approach to environmental sustainability. Through a meticulous analysis of the relevant literature, concession agreements, and reference texts, this research identifies critical environmental challenges, parameters, variables, and KPIs. It emphasizes that mere compliance with existing environmental regulations is insufficient. Ports must innovate, invest in green technologies, pursue advanced sustainable strategies and operational solutions, and foster an environmental culture across the industry.

The findings emphasize the importance of embedding clear environmental goals and KPIs into concession agreements, which actively drive progress toward sustainability. By incorporating advanced environmental terms, ports can reduce their ecological footprint while promoting sustainable growth. Moreover, the pivotal role of concessionaires in enhancing environmental performance within port operations is acknowledged. Concession agreements provide an opportunity to establish sustainability frameworks that engage industry while considering the interests of all stakeholders in a balanced manner.

By addressing these elements, this paper provides valuable insights for future research, policy development, and practical applications in the port sector, laying a solid foundation for more sustainable concession agreements. The authors emphasize the necessity of further research to refine and expand the findings, particularly in developing KPIs tailored to the specific needs and circumstances of individual ports. Future studies could focus on particular port activities, terminals, or case-specific scenarios, offering deeper insights through targeted analysis or case studies. Such research would contribute to creating a robust and adaptable framework for sustainable port management and development, ultimately paving the way for more effective and impactful port concession agreements.

Author Contributions: Conceptualization, C.P., C.C. and P.P.; methodology, C.P. and P.P.; investigation, C.P.; resources, C.P., P.P. and M.T.; data curation, M.T.; writing—original draft preparation, C.P.; writing—review and editing, C.P., C.C., P.P., M.T. and V.Z.; visualization, C.P. and P.P.; supervision, C.P.; project administration, C.P.; funding acquisition, C.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the "Hellenic Foundation of Research and Innovation", Grant No. 16107 "Greece 2.0. Basic Research Financing Action (Horizontal support of all Sciences), Subaction II, Funding Projects in Leading-Edge Sectors". The contents of this paper only reflect the views of the authors.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data supporting the findings of this study are available upon reasonable request from the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. European Sea Ports Organization (ESPO). Environmental Report 2024—EcoPortsinSights. 2024. Available online: https://www.espo.be/media/ESPO%20Environmental%20Report%202024.pdf (accessed on 24 October 2024).
2. European Sea Ports Organization (ESPO). Environmental Report 2023—EcoPortsinSights. 2023. Available online: https://www.espo.be/media/ESPO%20Environmental%20Report%202023.pdf (accessed on 24 October 2024).

3. Deloitte; ESPO. Europe's Ports at the Crossroads of Transitions. A Deloitte and ESPO Study. Deloitte. 2021. Available online: https://www.espo.be/media/Deloitte-ESPO%20study%20-%20Europe%E2%80%99s%20ports%20at%20the%20crossroads%20of%20transitions_1.pdf (accessed on 24 October 2024).
4. World Ports Sustainability Program. World Ports Sustainability Report. 2020. Available online: https://sustainableworldports.org/wp-content/uploads/WORLD-PORTS-SUSTAINABILITY-REPORT-2020-FIN.pdf (accessed on 24 October 2024).
5. Roberts, T.; Williams, I.; Preston, J.; Clarke, N.; Odum, M.; O'Gorman, S. Ports in a Storm: Port-City Environmental Challenges and Solutions. *Sustainability* **2023**, *15*, 9722. [CrossRef]
6. Puig, M.; Darbra, R.M. Innovations and insights in environmental monitoring and assessment in port areas. *Curr. Opin. Environ. Sustain.* **2024**, *70*, 101472. [CrossRef]
7. Puig, M.; Azarkamand, S.; Wooldridge, C.; Selén, V.; Darbra, R.M. Insights on the environmental management system of the European port sector. *Sci. Total Environ.* **2022**, *806*, 150550. [CrossRef]
8. Puig, M.; Wooldridge, C.; Michail, A.; Darbra, R.M. Current status and trends of the environmental performance in European ports. *Environ. Sci. Policy* **2015**, *48*, 57–66. [CrossRef]
9. Notteboom, T.; Pallis, A.; Rodrigue, J.P. Green port governance. In *Port Economics. Management and Policy*; Routledge: London, UK; New York, NY, USA, 2021; pp. 340–355. [CrossRef]
10. Alamoush, A.S.; Ballini, F.; Ölçer, A.I. Revisiting port sustainability as a foundation for the implementation of the United Nations Sustainable Development Goals (UN SDGs). *J. Shipp. Trade* **2021**, *6*, 19. [CrossRef]
11. Ashrafi, M.; Walker, T.R.; Magnan, G.M.; Adams, M.; Acciaro, M. A review of corporate sustainability drivers in maritime ports: A multi-stakeholder perspective. *Marit. Policy Manag.* **2020**, *47*, 1027–1044. [CrossRef]
12. Lam, J.S.L.; Van de Voorde, E. Green port strategy for sustainable growth and development. In Proceedings of the International Forum on Shipping, Ports and Airports (IFSPA) 2012: Transport Logistics for Sustainable Growth at a New Level, Hong Kong, China, 27–30 May 2012.
13. Hossain, T.; Adams, M.; Walker, T.R. Role of sustainability in global seaports. *Ocean Coast. Manag.* **2021**, *202*, 105435. [CrossRef]
14. Housni, F.; Boumane, A.; Rasmussen, B.D.; Britel, M.R.; Barnes, P.; Abdelfettah, S.; Maurady, A. Environmental sustainability maturity system: An integrated system scale to assist maritime port managers in addressing environmental sustainability goals. *Environ. Chall.* **2022**, *7*, 100481. [CrossRef]
15. Felício, J.A.; Batista, M.; Dooms, M.; Caldeirinha, V. How do sustainable port practices influence local communities' perceptions of ports? *Marit. Econ. Logist.* **2023**, *25*, 351–380. [CrossRef]
16. Notteboom, T. Concession agreements as port governance tools. *Res. Transp. Econ.* **2006**, *17*, 437–455. [CrossRef]
17. Chlomoudis, C.; Kostagiolas, P.; Pallis, P.; Platias, C. Advancing port sustainability: Essentials for a model concession agreement framework. *J. Infrastruct. Policy Dev.* **2024**, *8*, 3535. [CrossRef]
18. Pallis, A.A.; Notteboom, T.E.; De Langen, P.W. Concession agreements and market entry in the container terminal industry. *Marit. Econ. Logist.* **2008**, *10*, 209–228. [CrossRef]
19. Ferrari, C.; Parola, F.; Tei, A. Governance models and port concessions in Europe: Commonalities, critical issues and policy perspectives. *Transp. Policy* **2015**, *41*, 60–67. [CrossRef]
20. Theys, C.; Notteboom, T.E.; Pallis, A.A.; De Langen, P.W. The economics behind the awarding of terminals in seaports: Towards a research agenda. *Res. Transp. Econ.* **2010**, *27*, 37–50. [CrossRef]
21. Chlomoudis, C.; Pallis, P.; Platias, C. Environmental Mainstreaming in Greek TEN-T Ports. *Sustainability* **2022**, *14*, 1634. [CrossRef]
22. Notteboom, T.; Lam, J.S.L. The Greening of Terminal Concessions in Seaports. *Sustainability* **2018**, *10*, 3318. [CrossRef]
23. Arof, A.M.; Zakaria, A.; Rahman, N.S.F.A. Green Port Indicators: A Review. In *Advanced Engineering for Processes and Technologies II. Advanced Structured Materials*; Ismail, A., Dahalan, W.M., Öchsner, A., Eds.; Springer: Cham, Switzerland, 2021; Volume 147, pp. 237–256. [CrossRef]
24. Serra, P.; Codipietro, M.; Melis, A.; Fancello, G. A Review of Port KPIs Considering Safety, Environment, and Productivity as the Three Dimensions of Port Sustainability. In Proceedings of the International Conference on Computational Science and Its Applications, Proceedings, Part VII—ICCSA 2023 Workshops, Athens, Greece, 3–6 July 2023; Lecture Notes in Computer Science. Springer Nature: Cham, Switzerland, 2023; Volume 14110, pp. 577–593. [CrossRef]
25. Housni, F.; Maurady, A.; Barnes, P.; Boumane, A.; Britel, M.R. Indicators for monitoring and assessment of Environmental management systems in ports. In Proceedings of the International Conference on Innovation, Modern Applied Science & Environmental Studies (ICIES2020), Kenitra, Morocco, 25–27 December 2020; Volume 234. [CrossRef]
26. Bartosiewicz, A.; Kucharski, A. Indicators of port sustainability: The example of Baltic Sea container ports. *Sustain. Dev.* **2024**, *32*, 2371–2384. [CrossRef]
27. Styliadis, T.; Angelopoulos, J.; Leonardou, P.; Pallis, P. Promoting Sustainability through Assessment and Measurement of Port Externalities: A Systematic Literature Review and Future Research Paths. *Sustainability* **2022**, *14*, 8403. [CrossRef]
28. Rodrigues, K.T.; Ensslin, S.R. Environmental performance evaluation in ports: A literature review and future research guidelines. *Marit. Econ. Logist.* **2024**, *26*, 241–260. [CrossRef]

29. Lim, S.; Pettit, S.; Abouarghoub, W.; Beresford, A. Port sustainability and performance: A systematic literature review. *Transp. Res. Part D Transp. Environ.* **2019**, *72*, 47–64. [CrossRef]
30. Sislian, L.; Jaegler, A.; Cariou, P. A literature review on port sustainability and ocean's carrier network problem. *Res. Transp. Bus. Manag.* **2016**, *19*, 19–26. [CrossRef]
31. Balić, K.; Žgaljić, D.; Ukić Boljat, H.; Slišković, M. The port system in addressing sustainability issues—A systematic review of research. *J. Mar. Sci. Eng.* **2022**, *10*, 1048. [CrossRef]
32. Stein, M.; Acciaro, M. Value Creation through Corporate Sustainability in the Port Sector: A Structured Literature Analysis. *Sustainability* **2020**, *12*, 5504. [CrossRef]
33. Özispa, N.; Arabelen, G. Sustainability issues in ports: Content analysis and review of the literature (1987–2017). In Proceedings of the GLOBMAR 2018—Global Maritime Conference, Sopot, Poland, 19–20 April 2018; Volume 58. [CrossRef]
34. Da Silva, J.C.; Ensslin, S. Performance evaluation in the port sector: A systematic literature review. In Proceedings of the 10th Maritime Transport Conference, Barcelona, Spain, 5–7 June 2024. [CrossRef]
35. Bucak, U.; Başaran, İ.M.; Esmer, S. Dimensions of the port performance: A review of literature. *J. ETA Marit. Sci.* **2020**, *8*, 214–240. [CrossRef]
36. Davarzani, H.; Fahimnia, B.; Bell, M.; Sarkis, J. Greening ports and maritime logistics: A review. *Transp. Res. Part D Transp. Environ.* **2016**, *48*, 473–487. [CrossRef]
37. Bakhsh, W.; Fiori, C.; de Luca, S. Literature Review on the Smart Port: Evolution, Technological Development, Performance Indicators of Smart Ports. In Proceedings of the International Conference on Computational Science and Its Applications—ICCSA 2024 Workshops, Hanoi, Vietnam, 1–4 July 2024; Proceedings, Part IX. Springer Nature: Cham, Switzerland, 2024; pp. 340–357. [CrossRef]
38. Belmoukari, B.; Audy, J.F.; Forget, P. Smart port: A systematic literature review. *Eur. Transp. Res. Rev.* **2023**, *15*, 4. [CrossRef]
39. Bessid, S.; Zouari, A.; Frikha, A.; Benabdelhafid, A. Smart ports design features analysis: A systematic literature review. In Proceedings of the 13th International Conference on Modeling, Optimization and Simulation: "New Advances and Challenges for Sustainable and Smart Industries" (MOSIM2020), Agadir, Morocco, 12–14 November 2020.
40. De la Peña Zarzuelo, I.; Soeane, M.J.F.; Bermúdez, B.L. Industry 4.0 in the port and maritime industry: A literature review. *J. Ind. Inf. Integr.* **2020**, *20*, 100173. [CrossRef]
41. Puig, M.; Darbra, R.M. The role of ports in a global economy, issues of relevance and environmental initiatives. In *World Seas: An Environmental Evaluation*, 2nd ed.; Sheppard, C., Ed.; Elsevier: Amsterdam, The Netherlands; Academic Press: Cambridge, MA, USA, 2019; pp. 593–611. [CrossRef]
42. Puig, M.; Wooldridge, C.; Casal, J.; Darbra, R.M. Tool for the identification and assessment of Environmental Aspects in Ports (TEAP). *Ocean Coast. Manag.* **2015**, *113*, 8–17. [CrossRef]
43. Puig, M.; Wooldridge, C.; Darbra, R.M. Identification and selection of environmental performance indicators for sustainable port development. *Mar. Pollut. Bull.* **2014**, *81*, 124–130. [CrossRef]
44. Mahmud, K.K.; Chowdhury, M.M.H.; Shaheen, M.M.A. Green port management practices for sustainable port operations: A multi method study of Asian ports. *Marit. Policy Manag.* **2023**, *51*, 1902–1937. [CrossRef]
45. Hossain, T.; Adams, M.; Walker, T.R. Sustainability initiatives in Canadian ports. *Mar. Policy* **2019**, *106*, 103519. [CrossRef]
46. Darbra, R.M. Benchmark dynamics in the environmental performance of ports. *Mar. Pollut. Bull.* **2017**, *121*, 111–119. [CrossRef]
47. Vega-Muñoz, A.; Salazar-Sepulveda, G.; Espinosa-Cristia, J.F.; Sanhueza-Vergara, J. How to Measure Environmental Performance in Ports. *Sustainability* **2021**, *13*, 4035. [CrossRef]
48. Praharsi, Y.; Hardiyanti, F.; Puspitasari, D.; Akseptori, R.; Maharani, A. An Integrated Framework of Balance Scorecard-PESTLE-Smart and Green Port for Boosting the Port Performance. In Proceedings of the 6th North American International Conference on Industrial Engineering and Operations Management, Monterrey, Mexico, 3–5 November 2021; IEOM Society International: Southfield, MI, USA, 2021; pp. 1643–1653.
49. Saengsupavanich, C.; Coowanitwong, N.; Gallardo, W.G.; Lertsuchatavanich, C. Environmental performance evaluation of an industrial port and estate: ISO14001, port state control-derived indicators. *J. Clean. Prod.* **2009**, *17*, 154–161. [CrossRef]
50. Di Vaio, A.; Varriale, L.; Alvino, F. Key performance indicators for developing environmentally sustainable and energy efficient ports: Evidence from Italy. *Energy Policy* **2018**, *122*, 229–240. [CrossRef]
51. Rodrigues, V.; Russo, M.; Sorte, S.; Reis, J.; Oliveira, K.; Dionísio, A.L.; Monteiro, A.; Lopes, M. Harmonizing sustainability assessment in seaports: A common framework for reporting environmental performance indicators. *Ocean Coast. Manag.* **2021**, *202*, 105514. [CrossRef]
52. Battino, S.; del Mar Muñoz Leonisio, M. Smart ports from theory to practice: A review of sustainability indicators. In Proceedings of the International Conference on Computational Science and Its Applications—ICCSA 2022 Workshops, Malaga, Spain, 4–7 July 2022; Lecture Notes in Computer Science. Springer Nature: Cham, Switzerland, 2022; Volume 13381, pp. 185–195. [CrossRef]
53. De Oliveira, H.C.; You, J.; Coelho, A.P. Governing coalitions and key performance indicators of port governance. *Marit. Transp. Res.* **2021**, *2*, 100023. [CrossRef]

54. Mazibuko, D.F.; Mutombo, K.; Kuroshi, L. An evaluation of the relationship between ship turnaround time and key port performance indicators: A case study of a Southern African port. *WMU J. Marit. Aff.* **2024**, *23*, 499–524. [CrossRef]
55. Di Vaio, A.; Varriale, L. Management Innovation for Environmental Sustainability in Seaports: Managerial Accounting Instruments and Training for Competitive Green Ports beyond the Regulations. *Sustainability* **2018**, *10*, 783. [CrossRef]
56. Castellano, R.; Ferretti, M.; Musella, G.; Risitano, M. Evaluating the economic and environmental efficiency of ports: Evidence from Italy. *J. Clean. Prod.* **2020**, *271*, 122560. [CrossRef]
57. Martínez-Moya, J.; Vazquez-Paja, B.; Maldonado, J.A.G. Energy efficiency and CO_2 emissions of port container terminal equipment: Evidence from the Port of Valencia. *Energy Policy* **2019**, *131*, 312–319. [CrossRef]
58. Laxe, F.G.; Bermúdez, F.M.; Palmero, F.M.; Novo-Corti, I. Assessment of port sustainability through synthetic indexes. Application to the Spanish case. *Mar. Pollut. Bull.* **2017**, *119*, 220–225. [CrossRef]
59. Othman, A.; El-gazzar, S.; Knez, M. A Framework for Adopting a Sustainable Smart Sea Port Index. *Sustainability* **2022**, *14*, 4551. [CrossRef]
60. Pallis, A.A.; Vaggelas, G.K. Chapter 13—Cruise Shipping and Green Ports: A Strategic Challenge. In *Green Ports. Inland and Seaside Sustainable Transportation Strategies*; Bergqvist, R., Monios, J., Eds.; Elsevier: Kidlington, UK, 2019; pp. 255–273. [CrossRef]
61. Molavi, A.; Lim, G.J.; Race, B. A framework for building a smart port and smart port index. *Int. J. Sustain. Transp.* **2020**, *14*, 686–700. [CrossRef]
62. Taljaard, S.; Slinger, J.H.; Arabi, S.; Weerts, S.P.; Vreugdenhil, H. The natural environment in port development: A 'green handbrake' or an equal partner? *Ocean Coast. Manag.* **2021**, *199*, 105390. [CrossRef]
63. Sadiq, M.; Ali, S.W.; Terriche, Y.; Mutarraf, M.U.; Hassan, M.A.; Hamid, K.; Hassan, M.A.; Hamid, K. Future greener seaports: A review of new infrastructure, challenges, and energy efficiency measures. *IEEE Access* **2021**, *9*, 75568–75587. [CrossRef]
64. Lawer, E.T.; Herbeck, J.; Flitner, M. Selective Adoption: How Port Authorities in Europe and West Africa Engage with the Globalizing 'Green Port' Idea. *Sustainability* **2019**, *11*, 5119. [CrossRef]
65. Angelopoulos, J.; Chlomoudis, C.; Styliadis, T. Effect of global supply chain developments on the governance of port regulation. In *Port Management: Cases in Port Geography, Operations and Policy*; Pettie, S., Beresford, A., Eds.; Koganpage: London, UK; New York, NY, USA, 2018; pp. 62–93.
66. Argyriou, I.; Daras, T.; Tsoutsos, T. Challenging a sustainable port. A case study of Souda port, Chania, Crete. *Case Stud. Transp. Policy* **2022**, *10*, 2125–2137. [CrossRef]
67. Argyriou, I.; Sifakis, N.; Tsoutsos, T. Ranking measures to improve the sustainability of Mediterranean ports based on multicriteria decision analysis: A case study of Souda port, Chania, Crete. *Environ. Dev. Sustain.* **2022**, *24*, 6449–6466. [CrossRef]
68. Ignaccolo, M.; Inturri, G.; Giuffrida, N.; Torrisi, V.; A Sustainable Framework for the Analysis of Port Systems. European Transport/Trasporti Europei 2020, Issue 78, Paper n° 7. Available online: https://istiee.unict.it/sites/default/files/files/Paper%207%20n%2078.pdf (accessed on 8 November 2024).
69. Sugimura, Y. Public-private partnerships in Japan's cruise terminal operations. *Res. Transp. Bus. Manag.* **2022**, *45*, 100593. [CrossRef]
70. The World Bank/Public-Private Infrastructure Advisory Facility (PPIAF). Port Reform Toolkit, Second Edition. Module 4: Legal Tools for Port Reform. 2007. Available online: https://www.ppiaf.org/sites/ppiaf.org/files/documents/toolkits/Portoolkit/Toolkit/pdf/modules/04_TOOLKIT_Module4.pdf (accessed on 24 October 2024).
71. World Bank Group. Sample Port Concession Agreement. 2009. Available online: https://ppp.worldbank.org/public-private-partnership/sites/default/files/2024-08/Port%20Concession%202.pdf (accessed on 24 October 2024).
72. United Nations—Economic and Social Commission for Asia and the Pacific (ESCAP). Model Agreement Development of a Dry Port Under PPP Mode. Volume-II of the Final Report Is the Model Agreement for Development of a Dry Port Project Under PPP Mode in Asia-Pacific Region. 2016. Available online: https://www.unescap.org/sites/default/files/Volume%20II%20-%20Model%20Agreement%20-%20Dry%20Port%20PPP.pdf (accessed on 24 October 2024).
73. United Nations Economic and Social Commission for Western Asia and Islamic Development Bank. Public Private Partnership (PPP) for Ports Development and Operation. Final Report. 2020. Available online: https://www.unescwa.org/sites/default/files/event/materials/PPP%20for%20Ports%20Development%20and%20Operation_Final%20Report_.pdf (accessed on 24 October 2024).
74. European Bank for Reconstruction and Development (EBRD). Model Heads of Terms for Seaport Concession PPP Agreement. EBRD PPP Regulatory Guidelines Collection Volume I. 2024. Available online: https://www.ebrd.com/sites/Satellite?c=Content&cid=1395312941688&d=&pagename=EBRD/Content/DownloadDocument (accessed on 12 November 2024).
75. European Union. Directive 2014/23/EU of the European Parliament and of the Council of 26 February 2014 on the Award of Concession Contracts. *Off. J. Eur. Union* **2014**, *L94*, 1–64.
76. Juhel, M.H.; Container Terminal Concession Guidelines. Africa Transport Policy Program (SSATP). Working Paper No 107. 2017. Available online: https://www.ssatp.org/sites/default/files/publications/SSATPWP107-web.pdf (accessed on 24 October 2024).

77. United States Agency for International Development (USAID). Port Agreement Templates. 2018. Available online: https://pdf.usaid.gov/pdf_docs/PA00THCT.pdf (accessed on 24 October 2024).
78. Indian Ministry of Shipping, R.T. & H. Model Concession Agreement for Private Sector Projects in Major Ports. 2021. Available online: https://ppp.worldbank.org/sites/default/files/2024-09/MCAPort%20(1).pdf (accessed on 24 October 2024).
79. Alamoush, A.S.; Dalaklis, D.; Ballini, F.; Ölcer, A.I. Consolidating Port Decarbonisation Implementation: Concept, Pathways, Barriers, Solutions, and Opportunities. *Sustainability* **2023**, *15*, 14185. [CrossRef]
80. Hiranandani, V. Sustainable development in seaports: A multi-case study. *WMU J. Marit. Aff.* **2014**, *13*, 127–172. [CrossRef]
81. Alexandropoulou, V.; Koundouri, P.; Papadaki, L.; Kontaxaki, K. New Challenges and Opportunities for Sustainable Ports: The Deep Demonstration in Maritime Hubs Project. In *The Ocean of Tomorrow: The Transition to Sustainability*; Koundouri, P., Ed.; Springer Nature: Cham, Switzerland, 2021; Volume 2, pp. 173–197. [CrossRef]
82. Roh, S.; Thai, V.V.; Jang, H.; Yeo, G.T. The best practices of port sustainable development: A case study in Korea. *Marit. Policy Manag.* **2023**, *50*, 254–280. [CrossRef]
83. Acciaro, M.; Vanelslander, T.; Sys, C.; Ferrari, C.; Roumboutsos, A.; Giuliano, G.; Lam, J.S.L.; Kapros, S. Environmental sustainability in seaports: A framework for successful innovation. *Marit. Policy Manag.* **2014**, *41*, 480–500. [CrossRef]
84. Platias, C.; Spyrou, D. EU-Funded Energy-Related Projects for Sustainable Ports: Evidence from the Port of Piraeus. *Sustainability* **2023**, *15*, 4363. [CrossRef]
85. Argüello, G. Environmentally Sound Management of Ship Wastes: Challenges and Opportunities for European Ports. *J. Shipp. Trade* **2020**, *5*, 12. [CrossRef]
86. Di Vaio, A.; Varriale, L.; Trujillo, L. Management Control Systems in port waste management: Evidence from Italy. *Util. Policy* **2019**, *56*, 127–135. [CrossRef]
87. Pallis, A.A.; Papachristou, A.A.; Platias, C. Environmental policies and practices in Cruise Ports: Waste reception facilities in the Med. *SPOUDAI-J. Econ. Bus.* **2017**, *67*, 54–70.
88. Ducruet, C.; Martin, B.P.; Sene, M.A.; Prete, M.L.; Sun, L.; Itoh, H.; Pigné, Y. Ports and their influence on local air pollution and public health: A global analysis. *Sci. Total Environ.* **2024**, *915*, 170099. [CrossRef]
89. Notteboom, T.; van der Lugt, L.; van Saase, N.; Sel, S.; Neyens, K. The Role of Seaports in Green Supply Chain Management: Initiatives, Attitudes, and Perspectives in Rotterdam, Antwerp, North Sea Port, and Zeebrugge. *Sustainability* **2020**, *12*, 1688. [CrossRef]
90. Elsahragty, M.; Kim, J.L. Assessment and strategies to reduce light pollution using geographic information systems. *Procedia Eng.* **2015**, *118*, 479–488. [CrossRef]
91. Puig, M.; Raptis, S.; Wooldridge, C.; Darbra, R.M. Performance trends of environmental management in European ports. *Mar. Pollut. Bull.* **2020**, *160*, 111686. [CrossRef]
92. Therivel, R.; Gonzalez, A. Developing key performance indicators for strategic environmental assessment effectiveness: A systematic framework. *Impact Assess. Proj. Apprais.* **2024**, *42*, 240–250. [CrossRef]
93. Yang, Y.C.; Ge, Y.E. Adaptation strategies for port infrastructure and facilities under climate change at the Kaohsiung port. *Transp. Policy* **2020**, *97*, 232–244. [CrossRef]
94. Twrdy, E.; Zanne, M. Improvement of the sustainability of ports logistics by the development of innovative green infrastructure solutions. *Transp. Res. Procedia* **2020**, *45*, 539–546. [CrossRef]
95. Cunha, D.R.; Pereira, N.N.; de Santana Porte, M.; Campos, C.R. Sustainability practices for SDGs: A study of Brazilian ports. *Environ. Dev. Sustain.* **2024**, *26*, 9923–9944. [CrossRef]
96. García-Onetti, J.; Scherer, M.E.; Barragán, J.M. Integrated and ecosystemic approaches for bridging the gap between environmental management and port management. *J. Environ. Manag.* **2018**, *206*, 615–624. [CrossRef]
97. Akgul, B. Green port/eco port project-applications and procedures in turkey. *IOP Conf. Ser. Earth Environ. Sci.* **2017**, *95*, 042063. [CrossRef]
98. Argyriou, I.; Tsoutsos, T. Sustainable solutions for small/medium ports a guide to efficient and effective planning. *J. Mar. Sci. Eng.* **2023**, *11*, 1763. [CrossRef]
99. Duru, O.; Galvao, C.B.; Mileski, J.; Robles, L.T.; Gharehgozli, A. Developing a comprehensive approach to port performance assessment. *Asian J. Shipp. Logist.* **2020**, *36*, 169–180. [CrossRef]
100. Fobbe, L.; Lozano, R.; Carpenter, A. Proposing a Holistic Framework to Assess Sustainability Performance in Seaports. In *European Port Cities in Transition. Strategies for Sustainability. Moving Towards More Sustainable Sea Transport Hubs*; Carpenter, A., Lozano, R., Eds.; Springer: Cham, Switzerland, 2020; pp. 149–168. [CrossRef]
101. Milan, B.; Bootsma, S.; Bilsen, I. Advances in odour monitoring with E-Noses in the Port of Rotterdam. *Chem. Eng. Trans.* **2012**, *30*, 145–150. [CrossRef]
102. Geerts, M.; Dooms, M. Sustainability Reporting for Inland Port Managing Bodies: A Stakeholder-Based View on Materiality. *Sustainability* **2020**, *12*, 1726. [CrossRef]

103. United Nations. Framework Convention on Climate Change. In Proceedings of the Conference of the Parties Report of the Conference of the Parties on Its Twenty-First Session, Paris, France, 30 November–13 December 2015; Decision 1/CP.21 Adoption of the Paris Agreement, FCCC/CP/2015/10/Add.1; 29 January 2016. Available online: https://unfccc.int/resource/docs/2015/cop21/eng/10a01.pdf#page=2 (accessed on 14 November 2024).
104. European Commission. The European Green Deal. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2019) 640 Final, Brussels, 11 December 2019. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52019DC0640 (accessed on 14 November 2024).
105. Fernandez-Izquierdo, M.Á.; Ferrero-Ferrero, I.; Muñoz-Torres, M.J. Integrating Governance and Sustainability: A Proposal Towards More Sustainable Ports. In *European Port Cities in Transition. Strategies for Sustainability. Moving Towards More Sustainable Sea Transport Hubs*; Carpenter, A., Lozano, R., Eds.; Springer: Cham, Switzerland, 2020; pp. 225–239. [CrossRef]
106. Dathe, T.; Helmold, M.; Dathe, R.; Dathe, I. *Implementing Environmental, Social and Governance (ESG) Principles for Sustainable Businesses: A Practical Guide in Sustainability Management*; Springer Nature: Cham, Switzerland, 2024.
107. Gu, X.; Zhu, Y.; Zhang, J. Toward sustainable port development: An empirical analysis of China's port industry using an ESG framework. *Humanit. Soc. Sci. Commun.* **2023**, *10*, 944. [CrossRef]
108. Dos Santos, M.C.; Pereira, F.H. ESG performance scoring method to support responsible investments in port operations. *Case Stud. Transp. Policy* **2022**, *10*, 664–673. [CrossRef]
109. Dvorak, J.; Burkšienė, V. Sustainability Factors Shaping Port Security: A Case Study of Baltic Ports. In *Global Challenges in Maritime Security. Advanced Sciences and Technologies for Security Applications*; Otto, L., Menzel, A., Eds.; Springer Nature: Cham, Switzerland, 2024; pp. 81–111. [CrossRef]
110. Notteboom, T.; Verhoeven, P.; Fontanet, M. Current practices in European ports on the awarding of seaport terminals to private operators: Towards an industry good practice guide. *Marit. Policy Manag.* **2012**, *39*, 107–123. [CrossRef]