

The Pursuit of Green Ports: Addressing Environmental Impacts and Legal Hurdles in Development

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ABSTRACT:

The post-pandemic rebound of global maritime commerce demands the enlargement and modernization of seaports, but such expansion must be reconciled with increasingly clamorous demands for environmental stewardship. This paper explores "The Pursuit of Green Ports" while including a discussion on the two conflicting sides for the development of a port vs. conservation efforts. It delves into the nuanced environmental considerations at play in port expansion, including dredging, land reclamation, air and water pollution, and disruption of habitats. It also consists of an analysis of legal barriers port authorities and developers face in implementing sustainable measures. The study calls for the need for current international, national and regional law to be more effective in decreasing environmental harm and promoting green port projects. Namely the analysis of environmental impact assessment (EIA), compliance on the procedures, and the influences of international conventions such as MARPOL and UNCLOS, among others, on port development policies. Research addresses the challenges of integrating disruptive technologies, like alternative fuels, smart grids, and advanced waste management systems, into a port's operation while adhering to legal limits. It also addresses topics like the complexities of public-private partnerships and the need for transparent governance structures to make sure someone is being held accountable for environmental harms. It highlights lessons learned and best practices in green ports by a comparative review of its best practices around the world. In addition, the study analyses how local communities, environmental Non-Government Organizations (NGOs), global organizations, etc. have an impact on port development policies. This paper aims to potentially contribute to more sustainable port infrastructure with reduced environment impacts along with promoting economic development by identifying and addressing key legal gaps and regulatory mechanisms.

KEYWORDS: Green Ports, Port Development, Environmental Impact, Legal Hurdles, Sustainability, Maritime Trade

Introduction:

The growth of seaports is critical to global trade, allowing larger vessels to be serviced and increasing the amount of cargo handled by all seaports. However, these expansions have associated detrimental environmental impacts that require active management. As substantial contributors to both marine pollution and habitat destruction, and loss of biodiversity, ports are seen as having a notable role in sustainability in port development. This research explores the environmental issues of port expansion and

methods for creating sustainable and environmentally friendly ports. Concerns include the impacts of dredging and land reclamation on the marine environment, emission of carbon going to port operations, and impacts from industrial waste and oil spills on water quality.

If there are developments to address these issues, then innovative developments such as advances in renewable energy, green shipping standards, and improving waste facilities can be included in. By attempting to balance economic development with environmental sustainability, ports can reduce their carbon footprint while maintaining their efficiency and competitiveness.

Environmental Considerations in Port Expansion:

Expansion of seaports is essential to promote more global trade, larger vessels, and more volumes of cargo. This development, though, has immense environmental effects that must be addressed through sustainable planning and mitigation methods. Key challenges are loss of habitat, pollution, and loss of biodiversity, all of which call for a balanced strategy that balances economic development and nature conservation.

Dredging and Land Reclamation:

Land reclamation and dredging form the basis of port expansion through the creation of deeper berths for the giant vessels and the creation of new land for infrastructure. The operations have far-reaching environmental impacts.

Dredging, being a key operation in the development and maintenance of ports, has substantial environmental effects, particularly on marine life. Dredging also adds water turbidity, or re-suspension of bottom sediments, that decrease light availability, can negatively affect photosynthetic marine organisms like seagrasses and coral reefs. Loss of these resources results loss of the habitat and creates unstable ecosystems which can result in declines in marine organisms that are dependent on those resources.¹ Another area of concern is that contaminants residing in seabed sediments may also be released. Contaminants, like heavy metals, hydrocarbons, and industrial chemicals, when disturbed, may become mobile in the water column, thereby degrading water quality and potentially causing disastrous consequences for aquatic organisms and habitats.

Additionally, dredging affects coastal hydrodynamics by changing the topography of the seabed, which changes and disrupts tidal flows and sediment transport. Such changes to hydrodynamics can lead to undesirable and unknown effects, including erosion of the coast or excessive sedimentation in other places, representing a risk to natural and structural coastal infrastructure.² These environmental changes and considerations will be a part of the consideration during the planning, performing sustainable dredging operations, and monitoring the dredging prospects to reduce environmental impacts while sustaining functional capacity or commercial ports.

Land Reclamation Impacts:

Wetlands and mangroves play a key role in sequestering and storing carbon dioxide; the destruction and loss of these habitats releases sequestered carbon into the atmosphere thus increasing greenhouse gases and accelerating the pace of climate change. In addition to reducing habitat and ecosystem function, impacts could be mitigated through sustainable land reclamation practices that incorporate habitat

¹ Pecsvary, I., 2024. ADVANCING AND STRATEGIZING MARITIME ENVIRONMENTAL PROTECTION: A PATH TOWARDS A MORE SUSTAINABLE FUTURE. *Economic and Social Development: Book of Proceedings*, pp.78-99.

² Almeida, M.S.S., Borma, L.S. and Barbosa, M.C., 2001. Land disposal of river and lagoon dredged sediments. *Engineering geology*, 60(1-4), pp.21-30.

protection actions, anti-erosion practices, and stronger environmental policies that regulate port construction and land use, while simultaneously recognizing and reducing impacts on coastal habitats and the environment.

To lessen the ecological impact of port development, sustainable developmental approaches must be combined with active conservation processes. Sustainable dredging methods are one of the major approaches that can be used, making use of environmentally sensitive dredging methodologies, sediment containment systems, and in-situ monitoring devices to help mitigate ecological impacts. There are significant habitat restoration programs that offset habitat lost through dredging and land reclamation. Some of the steps that can be taken to restore important ecosystems that build marine life habitats and contribute to higher biodiversity include re-planting mangroves, constructing artificial reefs, and conducting wetland rehabilitation. Equally critical are the serious employment of Environmental Impact Assessments (EIA) and Strategic Environmental Assessments (SEA) to effectively steer port expansion developments. These assessments endeavor to ensure that environmental risks can be determined and that projects implemented by developers consider some ecological conservation practices initially designed into development plans.³

Air Pollution:

Ports release large quantities of greenhouse gases solely from the energy use required to load and unload vessels and from logistics. In conjunction with ship emissions and cargo handling, ports, with the associated truck traffic, are priority areas for address air pollution.

Mitigation of air pollution and health risks, can be achieved by implementing measures that promote the adoption of cleaner energy sources, alternative fuels, shore power facilities, and continuous electrification of port equipment. Air Quality Care Strategies: Several green strategies are being introduced to combat the environmental impacts of port operations by reducing emissions and fossil reliance.

Shore power is one of the most effective strategies, allowing ships to connect to the electrical grid when they dock, thereby removing the need for the onboard diesel generator, which leads to a large overall reduction in emission levels (sulphur oxides, nitrogen oxides and particulates) and cleaner air in and around the port. The shift to alternative fuels (liquid natural gas (LNG), hydrogen, biofuels, ammonia) is another approach to reduce emissions from shipping. These alternative fuels produce lower greenhouse gas emissions compared to more commonly used heavier fuel oil to create a 'greening' effect in shipping.⁴ As a result, the ECAs create incentive for shipping firms to increase cleaner fuels and emission reduction strategies, resulting in a shift towards more sustainable situations in the shipping industry. Ultimately, through effecting shore power, alternative fuels, electrified operations, and legislative action, ports can positively impact their environmental footprint while maintaining their operational output.

Water Pollution:

The discharge of ballast water is among the most major threats, as ships take up water (for balance reasons) and discharge it elsewhere, resulting in the introduction of invasive species which can overtake native species, and ruin local biodiversity. Spills from ships (or from fueling terminals), and lubricant spills from

³ Gupta, A.K., Gupta, S.K. and Patil, R.S., 2005. Environmental management plan for port and harbour projects. *Clean Technologies and Environmental Policy*, 7, pp.133-141.

⁴ Acciaro, M., 2015. Corporate responsibility and value creation in the port sector. *International Journal of Logistics Research and Applications*, 18(3), pp.291-311.

marine vessels are an additional serious threat to coastal economies and marine life, in that spills contaminate water and harm marine life. Industrial and chemical pollution from port activities are an additional issue, since poor waste management lead to heavy metal pollution, eutrophication, and contaminating surrounding waters with toxicity. From a synthesis of these issues, it is clear that tighter controls and environmentally-sound practices are necessary for the preservation and restoration of marine ecosystems. Water Pollution Mitigation Measures: In order to keep marine ecosystems free from pollution and contamination, a number of practices have been developed to regulate and operate vessels and ports. One example of an action is to install Ballast Water Treatment Systems as directed by the International Maritime Organization (IMO). These systems uses filtration, ultraviolet light treatment, or chemical biocides to manage invasive species before the boat releases ballast water into the ocean to avoid ecological upsets in ocean habitats. Moreover, Oil Spill Prevention Measures reduce the threat of ocean pollution. Ship maintenance on a regular basis, proximity of spill containment systems, and rapid response systems halt unintentional spills from flowing harmfully into the ocean. Additionally, Advanced Wastewater Treatment within ports is also necessary to maintain water quality. Through the implementation of closed-loop wastewater management systems, ports are essentially prevented from having pollutants in the ocean, thus maintaining environmentally sound shipping practices as well as conserving biodiversity.

Habitat Disruption and Biodiversity Loss:

Port development, though necessary for economic development and international trade, has deep environmental implications, seriously affecting marine and coastal biodiversity. The building and operation of new port infrastructure usually result in the destruction of habitats, pollution, and disturbances that destroy sensitive ecosystems. If not appropriately planned for and managed, these impacts can have long term consequences on marine life and coastal communities that depend on coastal resources.

Ship noise pollution, heavy machinery noise, and construction noise endanger marine life. Many marine animals, including whales and dolphins, depend on sound for communication, navigation, and migration. Underwater noise pollution engulfs their activities and generates disorientation, stress, and alteration to behaviours that may impair reproduction and survival. Chronic exposure to noise pollution may displace marine life from critical habitats, thereby disturbing the ecological environment. Minimizing biodiversity impacts. To address these risks and threats the creation of Marine Protected Areas (MPA) will help to conserve sensitive habitats and support at-risk species as development occurs around the newly constructed port. By creating some areas as a protected feature, the government will have facilitated biodiversity management through ecology, preventing the harm caused by development and allowing sustainable use of the marine grave." Another important strategy relates to the adoption of green port design, which includes green space, artificial reefs, and ecological buffer zones. Green port design will also allow biodiversity conservation to take place in areas of high industrial pressure through the provision of accessible habitats for aquatics and marine organisms while reducing the effects of construction activity. Finally, monitoring and compliance in order to maintain environmental sustainability is also key. The use of monitoring tools such as remote sensing, unmanned aerial vehicles and the use of acoustics can be used to study environmental change, and as a method for detecting violations, and to subsequently enforce actions if necessary.

Legal Barriers to Sustainable Port Development:

The transition to green port facilities is fraught with legal, regulatory, and governance challenges. Despite being at the heart of global trade, port development is frequently bogged down by legal issues that impact environmental conformity, transboundary regulatory enforcement, and application of green technology.⁵ Resolving these issues is a mix of robust environmental policy, effective governance arrangements, and global collaboration to promote sustainable development without environmental damage.

Environmental Impact Assessments (EIA) and Compliance:

Environmental Impact Assessments (EIAs) are a key tool used to evaluate the potential environmental impacts of port development projects. The assessments focus on identifying, mitigating, and monitoring environmental risks from construction, dredging, emissions, and waste disposal. However, their effectiveness is frequently undermined by numerous challenges:

When proper oversight is lacking, projects often move forward with little environmental review driven by economic and political factors that prioritize rapid development over environmental protection. This leads to hasty approvals without thorough environmental impact studies (EIAs) resulting in unchecked habitat loss and pollution. Regulatory gaps make the situation worse, as exceptions and outdated rules allow developers to avoid close scrutiny encouraging unsustainable port building. Lack of openness and public involvement in decision-making also creates problems. Limited access to EIA reports and few chances for public input reduce accountability, which erodes public confidence in port development plans. Without meaningful involvement, affected communities have no viable option to challenge environmentally destructive decisions, ultimately defeating the cause of sustainable and responsible port development.

Solutions to Strengthen EIA Compliance:

Governments must make environmental audits a periodic requirement in order to enable the monitoring of ecological impacts after the project is over too. Long-term assessment would enable them to identify unforeseen environmental impacts and take corrective actions to minimize damage. Tougher legal orders play a key role in closing gaps in rules and home-grown laws to match global green standards. With stricter rules to follow, governments can stop unsound building projects and help growth that lasts. Just as vital is getting the public and local groups involved, which ensures the environmental impact check (EIC) process is open and responsible. Bringing in local communities, charities, and outside experts offers many views making sure building plans think about both nature and people's needs. Strengthening these controls will be able to reconcile economic development with environmental protection and lead to more sustainable port development.

International Conventions and Regulatory Challenges:

International maritime laws and conventions give a model for sustainable port activity, yet variation in enforcement between jurisdictions is a significant challenge.

The International Convention for the Prevention of Pollution from Ships (MARPOL) aims to stop ships from polluting the seas. MARPOL has tough rules on emissions and waste management to cut down on

⁵ Butt, J. and Kousar, F., 2024. Harnessing offshore wind for sustainable economic growth in Nordic countries: Legal innovations, economic opportunities, SDG and policy integration. *Acta Universitatis Danubius. OEconomica*, 20(2), pp.123-145.

pollution from oil harmful liquids dangerous packaged goods, sewage, trash, and air pollutants.⁶ By setting high operating standards and pushing for eco-friendly tech, MARPOL plays a key role in keeping marine ecosystems safe.

The United Nations Convention on the Law of the Sea (UNCLOS) having a universal legal framework on managing the seas to address areas like territorial waters, right of navigation, and protection of the environment.⁷ The United Nations Convention on the Law of the Sea directs coastal states as well as flag states to establish practices against sea pollution like disposal control on toxic wastes and establishing polluters at fault.

Another significant agreement is the Ballast Water Management Convention, which examines the environmental risk that heavy ballast water discharges can create. The agreement reflects an effort for vessels to utilize ballast water treatment technologies and practices that will be compliant with the established standards that minimize damage to the environment.

As a group, these conventions constitute a robust regime of regulation for green maritime operation, so that maritime economic activity does not need to come at the cost of oceanic environmental well-being.

Challenges in Implementation:

Inequities between developing and developed nations significantly affect international environmental compliance because the former have both the funds and facilities to meet tougher regulations, and the latter face financial and technological constraints that make it hard for them to meet the requirements.

Additionally, varied national policies cause variations in emission quotas, waste management policies, and sustainability needs across countries, further complicating compliance.⁸ Second, there are the frailties of global enforcement authorities; although various international conventions establish regulations for environmental responsibility, the implementation of such norms relies significantly on national governments, and thus creates uneven compliance with global agreements.

Solutions to Enhance Regulatory Compliance:

In a bid to address environmental problems in port activities in an appropriate manner, various critical strategies can be employed.

Regional coordination and sharing of information, such as that demonstrated by the European Union's Green Port Strategy, provide exemplary models that facilitate the coordination of sustainability programs across borders. Further, offering incentives for compliance such as providing money and technical assistance to developing nations can cause these countries to adopt and implement green port programs, hence promoting a sustainable and environmentally conscious global maritime industry.

Public-Private Partnerships and Governance:

Public-private partnerships are increasingly regarded as being central to funding green port initiatives to assist in mobilizing private capital to facilitate sustainable infrastructure investment.

⁶ Hussain, N., Khan, A. and Memon, S., 2023. Addressing Marine Pollution: An Analysis of MARPOL 73/78 Regulations and Global Implementation Efforts. *Journal of Social Sciences Review*, 3(1), pp.572-589.

⁷ Bateman, S., 2007. UNCLOS and its limitations as the foundation for a regional maritime security regime. *The Korean Journal of Defense Analysis*, 19(3), pp.27-56.

⁸ Hasnat, M.A., 2024. The feasibility and challenges of implementing a green port policy framework in Bangladesh.

Concurrently, such collaborations pose significant governance issues. One of them is the possibility of profit incentives, where private investors would tend to concentrate on returns on investment at the expense of environmental sustainability. This will undermine ecological protection with cost-cutting measures.⁹ Moreover, the complex PPP arrangements may generate gaps in accountability, resulting in unclear environmental compliance obligations and complicating the attribution of accountability for non-compliance. Also, regulatory uncertainty generated by changing government policies and contradictory regulations can discourage private investment in green ports, reducing their general efficiency and sustainability. Governance of PPPs Strengthening:

In order to encourage a sustainable port development which is environmentally conscious, governments should create an open legal framework that includes clear and legally binding environmental obligations for private investors in the framework. The legal framework would also be supported by independent monitoring authorities with a specific mandate to ensure compliance and the ability to impose fines for any violations. In addition, the establishment of incentive-based policies (for example tax incentives, green financial products and subsidies for green technologies) could also prompt private income for green activities, stimulating further economic development while protecting the environment. Introduction of Disruptive Technologies. Technology innovations are perhaps the most series means to reduce the environmental footprint of port operations. The combination of alternative fuel sources, smart grid systems, and innovative trash management technologies may significantly speed the transition to more sustainable maritime infrastructure.

Technological developments in the digital age are allowing to shift port management systems with the intent of enhancing energy efficiency, reducing emissions, and complementing efficiency. Amongst key developments are smart grid technology, which enables ports to tap into renewables and supply electricity in a more efficient manner thus creating less energy waste.¹⁰ Automated logistics and AI powered systems use predictive insights and real-time monitoring of data to improve increasing efficiency in cargo handling and reducing delays and emissions. To further increase transparency in the supply chain, blockchain technology will allow the shipping industry to be accountable for sustainable shipping practices and the compliance with environmental regulations throughout the supply chain.

Circular economy values stress the importance of material reuse and recycling, reduction of waste output, while waste-to-energy technology converts waste from ports to renewable energy to enable sustainable power alternatives. Moreover, stricter regulations on waste disposal force ports to adopt segregation of wastes, promote biodegradable materials, and treat industrial waste effectively, rendering the maritime sector more sustainable.

Green Ports in India:

Some of the busiest ports around the world are implementing new green strategies to improve operational efficiency and fly under the radar with regards to carbon footprint and India is no behind.

The Indian government intends to make all inland waterways ports completely green within five years by harnessing renewable energy. T K Ramachandran, Secretary in the Ministry of Ports, Shipping, and

⁹ Di Vaio, A. and Variiale, L., 2018. Management innovation for environmental sustainability in seaports: Managerial accounting instruments and training for competitive green ports beyond the regulations. *Sustainability*, 10(3), p.783.

¹⁰ Schilling, J. and Logan, J., 2008. Greening the rust belt: A green infrastructure model for right sizing America's shrinking cities. *Journal of the American Planning Association*, 74(4), pp.451-466.

Waterways, announced the proposal during the FICCI Green Shipping & Ports Conclave 2024¹¹. Four major ports—Deendayal Port, Visakhapatnam Port, New Mangalore Port, and VOC Port—are already producing more renewable energy than they require.

The government has set a 2047 goal for converting all major ports in the country to green energy, and trial projects for green hydrogen generation are planned for Kandla, Tuticorin, and Paradip ports. The Shipping Corporation of India has also received funds to allow the use of methanol as a fuel in older ships.¹²

The Indian government's execution of the Maritime India Vision 2030, the Green Port Guidelines, the National Centre of Excellence in Green Port and Shipping, and the Sagarmala Programme are key efforts in promoting a sustainable and efficient maritime industry. Maritime India Vision 2030 aligns with India's goal of lowering emissions and increasing the usage of renewable energy.¹³ Over 150 proposals have been suggested for improving India's port, shipping, and waterways industries. The continuing implementation of this aim requires Indian ports to adopt greener port activities that are compatible with the country's overall plan. Another significant program, the Green Port Guidelines, aims to address environmental and sustainability issues in Indian ports.

The endeavour will start with Green Hybrid Tugs powered by Green Hybrid Propulsion systems and advance to non-fossil fuels such as methanol, ammonia, and hydrogen. The objective is to have the first Green Tugs operational at all major ports by 2025, with at least half of all tugs converted to Green Tugs by 2030, considerably decreasing environmental impact.¹⁴ The Indian government has created the National Green Mission and Green Hydrogen Policy to promote the usage of green hydrogen. Several commercial and public companies have invested in green hydrogen generation programs.

The Role of Stakeholders in Green Port Development:

When people's opinions are valued, they feel it's partly their duty to come up with better, lasting solutions. These groups help look after communities and nature when big industries move in.

There are some very big groups, like the International Maritime Organization and the World Bank, which help green port projects on a worldwide scale. They help these projects with money, support for rules, and expert advice. These groups give resources and set rules to encourage ports to be more earth-friendly.

It's crucial that different countries work together more. This helps the best ways of doing things spread far and wide. This makes sure that efforts to improve how green ports and sea activities are, is not only really good, but everyone knows about it too.

Conclusion:

The advancement of green ports is important to achieve both sustainable environmental practices and economic growth in the maritime industry. As ports grow to handle the increase in cargo and global trade, they must also confront questions relating to habitat destruction, pollution, and biodiversity loss. Green

¹¹ Federation of Indian Chambers of Commerce & Industry, *India Targets Ambitious Goal of Transitioning Coastal and Inland-Waterways Shipping to Renewable Energy* (Mar. 7, 2024), https://ficci.in/press_release_details/4865.

¹² Agarwala, N., 2022. Project Green Ports: Are Indian ports on the right track?. *Maritime Affairs: Journal of the National Maritime Foundation of India*, 18(2), pp.15-36.

¹³ Kumar, M.S.S. and Kasturi, G.V.K., *A COMPARATIVE STUDY ON IMPLEMENTATION OF GREEN PORT INITIATIVES AMONG INDIAN MAJOR PORTS TOWARDS SUSTAINABLE DEVELOPMENT*. *Sustainability and Innovation in Business Research and Economic Reforms*, p.1.

¹⁴ KUMAR, R., *GREEN PORT INITIATIVES, POLICIES AND STAKEHOLDER ENGAGEMENT IN INDIA*. (Issued 1st Feb 2023) <https://abpi.uk/wp-content/uploads/2025/03/01FE2501.pdf>

mitigation measures – such as sustainable dredging techniques, renewable energy considerations, and waste management practices – can all serve to lessen the environmental impacts of ports. Green practices and operations not only restore and support marine environments but they can also increase long-term economic viability through enhanced efficiencies and a more predictable regulatory environment.

Collaborative efforts by all parties, including governments and authorities, will be necessary to achieve each of these sustainable targets in India. Through continued efforts by incorporating new technologies and new environmental policies, there will continue to be a balance of economic activity within ports without compromising ecosystem health in areas surrounding ports. A significant commitment to green ports will bring a more sustainable and resilient maritime industry to future generations.