Green Port Initiatives and Blue Economy Clusters: Special reference from Major Ports of Tamil Nadu

Dr.M.Sekar, Postdoctoral Researcher, Lincoln University College, Malaysia
Dr. Thiruppathi. KTM, Honorary Fellow, Lincoln University College, Malaysia

Abstract

This study is done by using a mixed-methods design, as it's a unique in nature, to analyse how green port initiatives effect sustainable blue economy outcomes at Tamil Nadu's Major Port, that is Chennai, Kamarajar, and V.O.C. ports. It measures localized environmental funds and discovers the institutional, financial, and regulatory features shaping their integration.

The quantitative phase assesses secondary performance data against international benchmarks whereas the qualitative phase uses thematic analysis for the research by conducting stakeholders' interview. Early findings disclose a clear Incongruity: Chennai Port is beginning solar deployment, Kamarajar port emphasizes on wetland restoration, and V.O.C port banks on green hydrogen projects. Effective maritime sustainability requires combining regulatory directives with systematic leadership, green finance, and community engagement.

Keywords: Green Ports, Blue Economy, Sustainability, Chennai Port (ChPT), Kamarajar Port (KPL), V.O. Chidambaranar Port (VoC), Harit Sagar guidelines.

1. Introduction

India's maritime imitative has shifted from concentrating on cargo throughput to shifting to blue economy paradigm, treating ports, oceans and coasts as an integrated system requiring environmental governance. As critical economic drivers, ports create a significant ecological environment. The researcher finds Chennai port, Kamarajar Port and VoC port is an ideal element for the study, because these cluster cluster handles large trade volumes while sitting across ecologically sensitive zones, making it an excellent unit for evaluating how green port initiatives interact with larger sustainability goals.

The Ministry of Ports, Shipping and Waterways mandates sourcing 60% of major ports' energy from renewables by 2030 under Maritime India Vision. The Harit Sagar Guidelines and Indian Ports Act,2025 also stress more on environmental adherence with international conventions as a statutory requirement.

This study evaluates how this Ecological discourse into practice across the three major ports and clarifies their operational variations.

2. Literature Review

2.1 The Blue Economy Concept:

The blue economy gained prominence following the United Nations Conference on Sustainable Development, in 2012, it was framed as an extension of the green economy concept to ocean and coastal frameworks, a later reinforced by Sustainable Development Goal 14's to conserve and sustainably use oceans, seas, and marine resources. In the Indian design, voiced in NITI Aayog's (2021) draft national policy on the blue economy, the concept is treated as a multidimensional and inter-sectoral domain encircling fishery, ports & shipping, offshore energy, tourism in coastal areas, and biotechnology, together by the principle that economic activity in and around the sea which should not compromise the pliability of marine and coastal ecosystems.

2.2 The Green Port Concept:

A parallel reputable literature addresses the environmental performance of ports specifically, situated within the broader field of port economics, management, and policy (Notteboom et al., 2022), and ante ceding much of the blue economy discourse. Darbra et al. (2005) were among the first to develop a methodical procedure for classifying the significant environmental aspects of port procedures, including air emissions, water quality, noise, and waste. This work nourished into a broader green port literature that sets the management tools available to port authorities. Lam and Notteboom (2014), in a extensively cited comparison of leading ports in Europe and Asia gathered these tools into categories such as pricing and incentive schemes, monitoring and measurement systems, market access controls, and direct investment in cleaner infrastructure.

Acciaro et al. (2014) argued that port officials are increasingly assuming an energy management role reserved for utilities, whereas Acciaro and Wilmsmeier (2015) and Wilmsmeier and Spengler (2016) showed that on site renewable generation and energy efficiency measures can deliver direct operating cost savings in addition to environmental benefits. Castellano et al. (2020), examining ports in Italy, found that ports with a stronger pro-environmental alignment tend to exhibit improved economic efficiency rather than facing an unescapable trade-off between greening and competitiveness. Chen and Pak (2017) extended this evaluative literature with a Delphi relied set of green performance indices for ports in China, in fact Wan et al. (2018) projected a quantitative model for benchmarking green port expansion across major ports in China, showing the growing methodological superiority of green port assessment. Lam and van de Voorde (2012) had earlier planned an integrative green port strategy context built on stakeholder involvement, green market development, and cost-effective green policy, get ahead much of this successive measurement literature. Poulsen et al. (2018) cautioned that most green port measures think on seaside and terminal interface, comparatively with little attention focused to inland transport emissions, this gap especially very relevant for Indian ports where hinterland connectivity is being upgraded under Sagarmala and the National Logistics Policy.

The port sustainability research is expanding rapidly but remains disjointed, skewed toward environmental indicators comparative to social and economic factors, and loosely connected to global contexts like the United Nations Sustainable Development Goals (Alamoush et al., 2021). Styliadis et al. (2022), in a methodical literature review of port externality valuation and measurement, similarly call for greater procedural consistency and for research that explicitly links green measure at port level for a broader regional or sectoral sustainability outcomes, a gap into which a blue-economy cluster mounting of Tamil Nadu's ports is intended to speak. Notteboom et al. (2020), probing seaports in the Rotterdam, Antwerp, North Sea Port, and Zeebrugge range, to add further the hunt for a green port image and expectation from stakeholders has become an important driver for port greening, apart from regulatory compliance.

2.3. Green Maritime Odyssey:

The Ministry of Ports, Shipping and Waterways' (2021) Maritime India Vision 2030 sets targets, for increasing the renewable energy share of total port power consumption to sixty per cent, achieving at least fifty per cent electrification of port equipment, and extending shore to ship power supply to the vessels berthing at the port. The Green Tug Transition Programme matches these efforts by replacing diesel powered tugs with electric powered at major ports. The Indian Ports Act, 2025 has elevated environmental compliance aligning with international conventions to a statutory format.

This indicates a clear picture for research treating Chennai Port, Kamarajar Port, and V.O.C Port not as remote cases but as a regionally interconnected cluster, agreeing that their collective environmental performance has implications for the greater sustainable blue economy of the East coast of India.

3. Objectives and Research Questions:

This study focuses on two primary objectives: first, to evaluate the effectiveness of green port initiatives at three major ports of Tamil Nadu enabling sustainable blue economy outcomes; and second, is to identify the aspects influencing their integration into planning. These objectives has spelt out two research questions:

1. What green port drivers are operational across major ports in Tamil Nadu, and how they effectively keep up the sustainable blue economy clusters?
2. What institutional, financial, and regulatory framework shall enable or restrict green practice integration in these regions (port city)?

4. Limitations

The data were provided as a port level frequency sums per item, circulated with 50 respondents on each port's stakeholders, rather than as a respondent-by-item background, it is not possible to create which individual gave which mixture of responses across the four items. All three require a linked respondent by item dataset. In fact, the research team wish to pursue these analyses, future data collection should retain individual respondent identifiers or sometimes and record each respondent's full set of four responses in a single row, rather than aggregating responses into port-level frequency counts before analysis.

5. Research Methodology

The study follows a mixed-methods approach. The quantitative phase creates green performance contours by analysing secondary data on emission, energy, and waste from the reports of Major port. To apprehend internal operational parameters, a structured questionnaire was circulated to port officials, and the data obtained was analysed using statistical tools.

The qualitative aspect with a semi-structured interview with stakeholders, terminal operators, and coastal communities were conducted.

Descriptive Statistics

The table shows the mean, standard deviation, and percentage distribution of responses for each item.

Particulars	Port	Mean	SD	%SD	%D	%N	%A	%SA
Renewable energy initiatives have reduced energy-related environmental impact	ChPT	3.22	0.62	0	6	70	20	4
	KPL	3.70	0.79	0	2	44	36	18
	VOC	4.90	0.30	0	0	0	10	90
Waste, effluent, and water management practices are effective	ChPT	3.50	0.68	0	0	60	30	10
	KPL	4.44	0.67	0	0	10	36	54
	VOC	4.54	0.58	0	0	4	38	58
Biodiversity and ecosystem conservation initiatives have benefited communities	ChPT	3.34	0.89	4	10	4	40	6
	KPL	4.42	0.61	0	0	6	46	48
	VOC	4.62	0.57	0	0	4	30	66
Overall contribution to sustainable blue economy outcomes	ChPT	4.02	0.94	2	4	18	42	34
	KPL	4.74	0.49	0	0	2	22	76
	VOC	4.44	0.76	0	0	16	24	60

{Table: Mean, SD and percentage response delivery by item and port (n=50per port with scale1=Strongly Disagree to 5= Strongly agree)}

From the above, VOC Port and Kamarajar Port logged higher mean agreement scores compared to Chennai Port, with Chennai's means clustering between 3.22 and 4.36 (that is the lowest of the three ports on every item) and the other two ports generally scoring above 4.4. The gap is widest on the renewable energy item, where Chennai's mean of 3.22 trails V.O. C Port's 4.90 by more than a full-scale point, dependable with the difference in solar and wind capacity already in operation at the two ports. The other variables are self-explanatory.

6. Green Port Initiatives adopted in the above Ports: Review from the Secondary data:

6.1 Chennai Port

Chennai Port, one of oldest in the cluster, is aggressively closing its renewable energy deployment gap. The Port Authority has floated tenders for a 2 megawatt-peak (MWp) grid-connected rooftop solar photovoltaic system on cargo sheds and transit sheds under a renewable energy service company (RESCO) model. They are actively proposing to install grid-connected solar and wind capacity to support day to day operations and also started implementing shore to ship supply. Since Chennai port is a cash rich port after acquiring KPL is poised to increase green model there by increasing the share of renewable energy.

6.2 Kamarajar Port (KPL)

KPL is India's first corporatized major port, boons a more mature green profile due to its newer infrastructure and ecologically sensitive coastal setting. Operating under the national *Harit Sagar* framework, its Health, Safety and Environment division manages marine pollution, climate resilience, and biodiversity protection. The terminal operators draw roughly 30% of their energy from renewable sources, contributing to a combined green power share across the port of roughly 65% in the 2025–26 financial year.

The port has invested around Rs. 20.5% crore in shore to ship power supply infrastructure Beyond its operational borders, the port addresses blue economy goals by funding ecosystem restoration in the Ennore wetlands, removing dredged material, planting mangroves, and restoring fish cultures to support local fishing livelihoods.

6.3 VOC Port

V.O.C Port displays the cluster's progressive green profile, integrating environmental investments with wider blue economy determinations. The port operates with a 5-megawatt (MW) groundbased solar plant, a 2 MW wind plant, and over 1 MW of rooftop solar capacity, with another 1 MW ground-based facility which is under construction. In the year 2024-25, these assets generated over 12 million units of green power, shifting more than 10 million kilograms of carbon dioxide emissions. Its administration building is the first among major Indian ports to achieve the Indian Green Building Council's (IGBC) platinum rating, operating entirely on renewable energy alongside Bureau of Energy Efficiency (BEE) Shunya and Shunya Plus net zero and net positive certifications for several structures.

V.O.C Port has launched an indigenous hydrogen fuel cell ferry, is also developing a green hydrogen pilot plant, and has signed an MoU for an integrated green ammonia production, storage, and bunkering hub representing a potential investment around Rs.50000 crore. Furthermore, the port is monetizing its renewable portfolio through carbon credits, expected to yield roughly Rs.50 Crore over a decade.

7. Conclusion

7.1 Discussion and Findings

When we look into the above study it is understood that the though the there is a uniform framework chartered by the National agencies whereas there is distinct feature that exist across the ports and its cluster which are actually driven by the local issues.

From the structural design the program like Harit sagar framework has offered read to implement operational formula. Whereas the leadership in VoC port has to be commended for accelerating strategic partnerships which has pushed the fuel projects beyond the standards specified in regulation. The voice from the fisherfolk and other close stake holders near KPL that is in Ennore wetlands has effectively pushes the ports towards backing and funding the critical ecosystem restoration, which was very evident from the study.

Chennai Port which was urban locked faces a land crunch to implement solar panel deployment, though they are cash rich.

From the semi-structured interviews, it is understood shore power adoption is very slow due to heavy cost involved in retrofitting for the owners of commercial vessel added to that there is also administrative delays in ports and other agencies.

7.2 Summary of Conclusion:

This paper examines and found that though the uniform national policies are been rolled out, the reality is bit sour due to institutional, spatial and financial constraints. It is easy to cement these gaps, suggested to have National Maritime Policy towards case to case basis and also to support green monetization strategies. The system should accept and adopt a cluster design analytics so that it may provide important and scalable visions for creating a great green transition across all ports both Major as well as non-major ports.

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