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The Sagarmanthan Review: Navigating the Great Oceans

Edited by

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WILEY

The Sagarmanthan Review:
Navigating the Great Oceans

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FOREWORD

The inaugural 'Sagarmanthan: The Great Oceans Dialogue,' held in New Delhi on 18-19 November 2024, marked a pivotal moment in India's growing maritime engagement. Jointly convened by the Ministry of Ports, Shipping and Waterways and the Observer Research Foundation, the Dialogue created a unique space for diverse voices—particularly those from the Global South and small island nations—to come together and deliberate on the future of our oceans. It reaffirmed the need for global collaboration rooted in equity, innovation, and sustainability.

The oceans are more than economic lifelines; they are strategic gateways that connect nations, drive innovation, and shape global prosperity. As maritime activity becomes more complex and interconnected, the seas represent not only a vast opportunity but also shared responsibility. We are witnessing a major transition in the maritime domain, driven by technological advances, climate imperatives, shifting geopolitics, and the growing call for inclusive, sustainable development. With over 90 percent of global trade flowing by sea, this evolving landscape holds critical implications for economies and communities worldwide.

India is playing an active role in shaping the future of maritime governance, leveraging its strategic location, deep-rooted maritime heritage, and expanding global influence. As we progress toward our goal of becoming the world's third-largest economy by 2027, robust maritime infrastructure will be a key driver of growth. Our national vision is reflected in a series of initiatives aimed at modernising ports, streamlining logistics, and promoting sustainable development. These include the Sagarmala programme, which focuses on port-led development; Maritime India Vision 2030, charting a blueprint for sectoral growth; and the long-term roadmap of Amrit Kaal Vision 2047. Beyond our shores, India is also championing regional collaboration through frameworks and corridors such as the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation and the India-Middle East-Europe Economic Corridor.

At the same time, the maritime economy is evolving beyond ships and ports. Digitalisation, decarbonisation, and sustainable innovation are redefining what it means to be a maritime nation. India is embracing this shift—developing green ports, promoting responsible ship recycling, and adopting smart technologies to build a resilient, future-ready maritime sector. We are equally committed to ensuring that this transformation is

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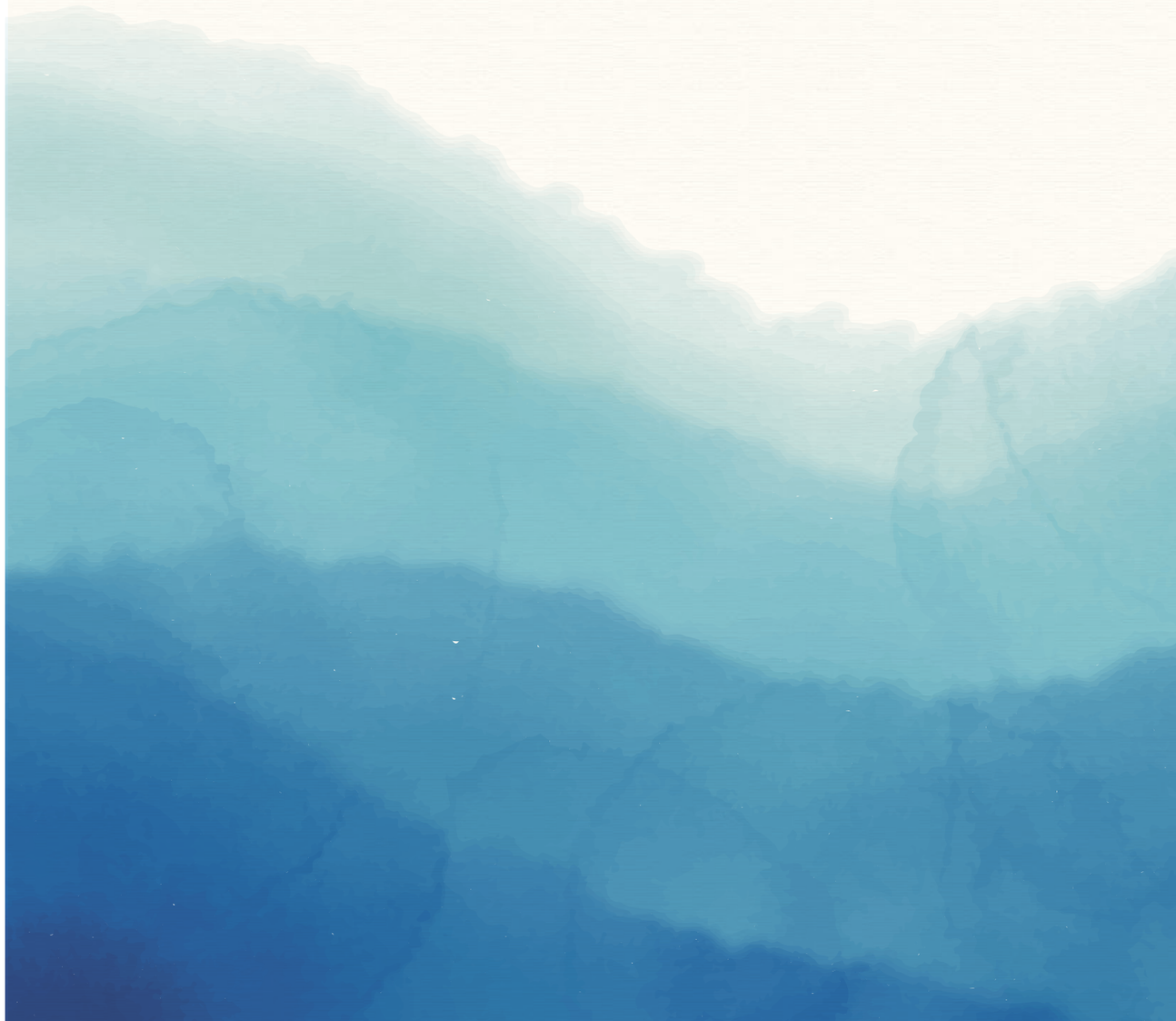
inclusive—one that empowers coastal communities and makes them central to our maritime journey.

In this context, *The Sagarmanthan Review: Navigating the Great Oceans* makes a timely and valuable contribution to global maritime thought. Drawing from the rich deliberations of the Sagarmanthan Dialogue, and bringing together expert insights from 20 countries, this compendium offers a platform for constructive dialogue on the evolving maritime landscape. It reflects a collective aspiration: to strengthen maritime partnerships, bolster resilience and sustainability, and develop inclusive frameworks that prioritise the well-being of coastal communities.

As we chart new maritime pathways, this collection of perspectives serves as both a compass and a call to action—reminding us that the oceans, while vast, are shared. Their stewardship depends on collective wisdom, bold partnerships, and an enduring commitment to equity. I commend the contributors to this volume for their insightful essays and encourage policymakers, industry leaders, and scholars to engage deeply with the ideas presented here to help shape a more resilient and inclusive maritime world.

(T. K. Ramachandran)

Introduction



With over 90 percent of global trade reliant on sea routes, maritime governance is critical to secure supply chains, ensure equitable resource access, and foster economic resilience (1). The maritime domain is also witnessing renewed geopolitical competition even as it offers a variety of new investment opportunities. These are implicating and, in turn, are shaped by both state and non-state actors seeking to navigate an evolving maritime landscape (2).

At the same time, ports and shipping are also undergoing a transformation; they are transforming from traditional trade and logistics gateways to platforms of technology, virtual economic exchanges, and digital connectivity, positioning maritime cities and industries as regional and global innovation engines for sustainable blue growth (3). However, as the climate crisis intensifies, coastal communities face disproportionate risks, highlighting the need for inclusive, people-centric development that balances economic ambition with environmental sustainability (4).

These macro trends need to be factored in even as India seeks to shape maritime governance in the region and beyond, leveraging its growing economic heft, strategic location in the Indo-Pacific, and active engagement in regional and global frameworks (5, 6). Given that 95 percent of India's trade by volume moves through sea routes, robust maritime infrastructure is essential to India's aspiration of becoming the world's third-largest economy by 2027 (7, 8). National initiatives such as 'Sagarmala', 'Maritime India Vision 2030', and 'Amrit Kaal Vision 2047' aim to build a more sustainable blue economy, aligned with the SAGAR principle—security and growth for all in the region (9). These efforts focus on expanding domestic shipbuilding, modernising ports, and improving logistics networks.

India is also strengthening international connectivity through corridors such as the India-Middle East-Europe Economic Corridor and regional partnerships such as the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation and the Indian Ocean Rim Association, which promote trade, maritime governance, and regional cooperation (10). At the same time, the integration of technologies through artificial intelligence (AI), the Internet of Things, and satellite technologies is driving efficiency and decarbonisation (11). India's target of achieving net-zero emissions by 2070—alongside green port development and ship recycling initiatives—reflects its commitment to building a more sustainable maritime sector (12, 13).

Meanwhile, the global demand for critical minerals is driving investment in resilient, diversified supply chains (14). Yet, ensuring maritime growth benefits local communities remains a challenge, especially for India, with its vast 11,098 km coastline and 72 coastal districts (15, 16). This highlights the need to ensure development in the maritime sector is inclusive, sustainable, and fair. A people-first approach—centred on job creation, skills training, and support for local enterprise—can ensure coastal communities benefit directly from maritime growth. For this, blue economy initiatives must be participatory, sustainable, and locally grounded—not just in India, but across coastal nations facing similar transitions.

The pursuit of inclusive maritime development at the national level must align with and contribute to broader global efforts. Strengthening resilience, fostering cooperation, and preparing for disruptions—such as oil spills, pandemics, and piracy—are essential to secure the global maritime future (17). Amid shifting geopolitics, climate challenges, and evolving trade routes, technological integration and inclusive growth will be key. Advancing innovation, building partnerships, and promoting people-centric development must remain central to the global agenda. In this context, this compendium, *The Sagarmanthan Review: Navigating the Great Oceans*, offers a timely and important ideas platform that collates insights and perspectives from eminent experts across geographies who share a commitment to strengthen the maritime sector by deepening partnerships, helping catalyse investments in resilience and sustainability, and discovering pathways that allow the potential growth of this sector to benefit local communities significantly.

It builds on the discussions hosted at the inaugural edition of 'Sagarmanthan: The Great Oceans Dialogue', an annual convening co-hosted by the Observer Research Foundation (ORF) and India's Ministry of Ports, Shipping and Waterways. This global dialogue aims to serve as a platform to strengthen collaboration between various stakeholders to develop an inclusive, resilient, and sustainable ocean economy. It brings together policymakers, industry leaders, scholars, and civil society representatives to exchange insights on critical themes. The inaugural dialogue—held in New Delhi on 18 and 19 November 2024—focused on maritime connectivity and infrastructure, the role of partnerships in economic development, sustainability and technology, and community-centred governance.

This compendium offers well-researched analyses and actionable recommendations to shape maritime strategies aligned with economic, social,

and environmental goals. Organised into four sections, the first part explores ways to enhance global maritime connectivity through multimodal transport corridors, optimised trade networks, and smart infrastructure investments. The second section focuses on fostering strategic partnerships between India, the Global South, and other regions to strengthen regional cooperation. The third section highlights sustainability imperatives, such as climate change-driven maritime routes, decarbonisation, AI-powered maritime efficiencies, and biodiversity conservation. The final section underscores the importance of people-centric policies to build resilience and adaptability in the face of emerging ocean challenges.

The significance of this publication extends beyond national borders—maritime challenges and opportunities are inherently global, requiring collaboration across regions and disciplines. Featuring 25 essays, the publication brings together diverse perspectives by internationally renowned experts from 20 countries, with contributions spanning Europe, Asia, the Gulf, Oceania, the Americas, the Caribbean, the Indian Ocean Region, and Africa. It includes a strong representation from maritime nations in the Global South and Small Island Developing States, whose insights are necessary to shape any inclusive and sustainable maritime policy framework for the future.

Focusing on maritime policy and international cooperation, Bruce Jones examines the evolving geopolitical landscape and emphasises the importance of resilient maritime partnerships. Tomasz Łukaszuk highlights shared challenges and opportunities in port development between the European Union (EU) and India, while Ashraf Keshk explores maritime security collaboration between India and the Gulf States. Peter Chatlani draws insights from Panama's canal and port development to inform India's coastal policy. Mads Qvist Frederiksen turns our attention to the Arctic, discussing the potential for a sustainable blue economy for that region, while Erin Watson reflects on how smart port technologies are reshaping global trade.

In the context of blue growth, Nadeem Nazurally underscores its promise for island and coastal states, while Juita Mohamad stresses Asia's need to align economic development with environmental priorities. Teenah Jutton advocates for stronger representation of Southern perspectives in global blue economy dialogues. Raimund Bleischwitz and Rüya Perincek propose a circular maritime economy model rooted in India-EU cooperation, while Ruben Eiras discusses the role of AI in advancing triple-use investments in the blue economy, particularly through Portugal-India partnerships.

On sustainability and innovation, Ahmed Hussein Selim outlines challenges to environmental sustainability in Indian shipping. Nancy Karigithu offers a global vision for greener maritime practices, while Linda Etta identifies both barriers and breakthroughs in marine transport sustainability. Ayla Bajwa calls for integrated frameworks to break sectoral siloes in maritime governance, and Nwabisa Matoti charts a roadmap for decarbonising the industry. Paritosh Deshpande and Yogindra Samant promote sustainable ship recycling as a dual strategy for green growth and worker safety, while Tanuja Kaushik and Rahul Akolkar highlight the importance of maritime innovation. Nicole van Spronsen shares the Netherlands' journey toward zero-emission inland shipping.

Finally, this volume emphasises inclusive maritime governance and its far-reaching social impact. Mohamed Nasheed proposes alternative, traditional, and cost-effective solutions to decarbonise the maritime industry, championing island-led leadership in this effort. Malshini Senaratne explores governance models that prioritise coastal communities in blue economy planning. Senthilkumaran Krishnan offers a framework for building resilient, climate-adaptive coastal societies, and Vishal Surbun underscores the importance of meaningful public participation in ocean governance. Ishita Sharma reflects on port development that balances economic ambition with social responsibility, and Anusha Kesarkar Gavankar and Katharina Bothe conclude by emphasising that the future of the blue economy must be grounded in the lived experiences of local communities, guided by social equity, and enriched by the wisdom of indigenous knowledge.

Together, these contributions offer actionable insights to shape equitable and sustainable maritime futures.

We extend our sincere gratitude to the distinguished authors, policymakers, and thought leaders who have shared their knowledge and expertise. We deeply appreciate their willingness to share valuable research, innovative ideas, and policy recommendations. These global perspectives not only enrich this discourse but also reinforce the shared responsibility of ensuring a sustainable and inclusive ocean economy. The Sagarmanthan Review: Navigating the Great Oceans stands as a testament to this collective effort, advancing dialogue that will shape India's maritime aspirations and contribute meaningfully to global conversations on the future of our oceans for generations to come.

Katharina Bothe **Anusha Kesarkar Gavankar**

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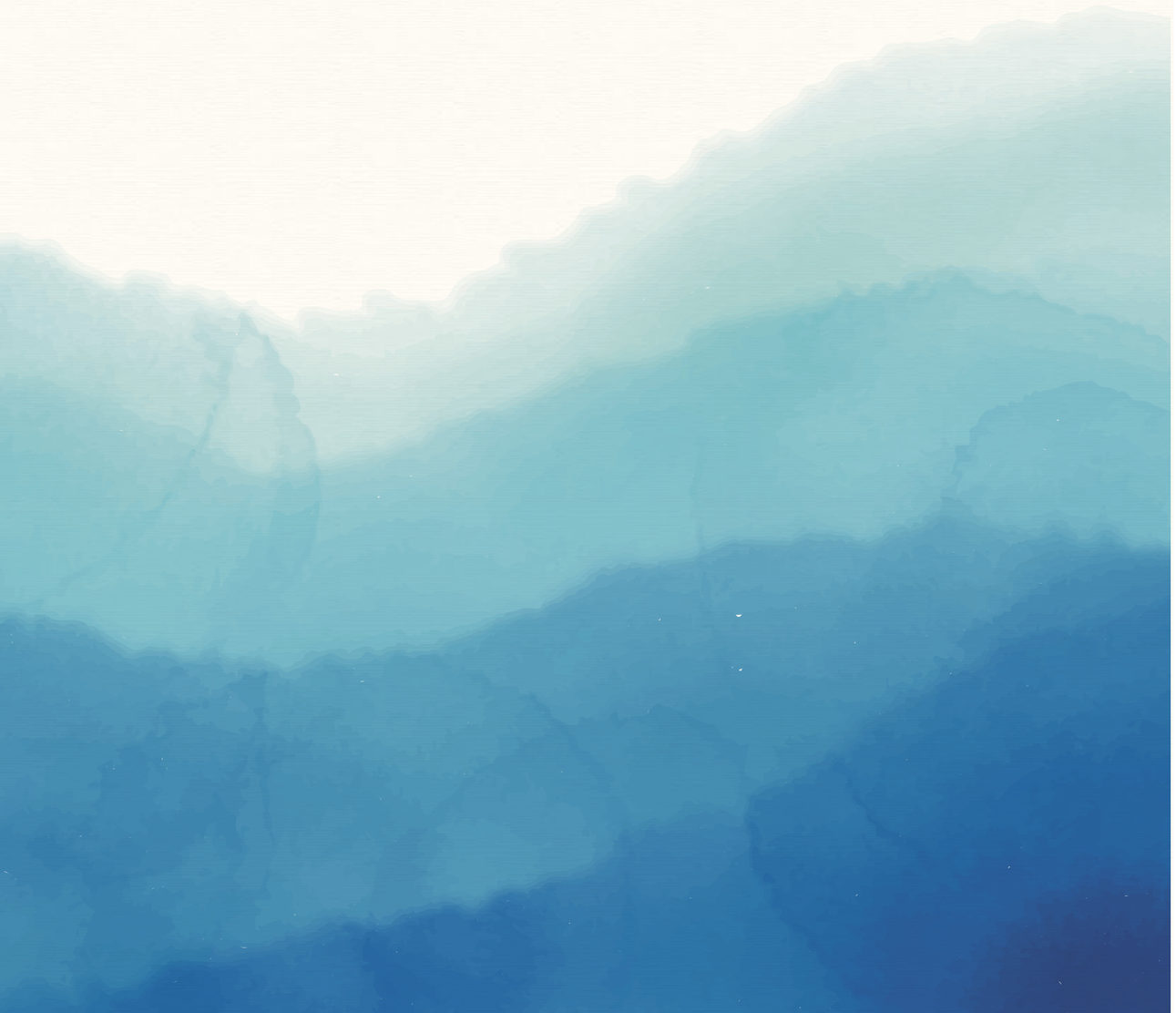
Section I

New Frontiers: Connectivity, Infrastructure, and Development in a Changing World

Maritime Partnerships in an Era of Turbulence

Bruce Jones



One of the most consequential facts of contemporary world politics is China's large and still-growing maritime presence (commercial, naval, and scientific), marking a return to the high seas after a 500-year absence (1). The reverberations of this are still playing out amid the start of another development that could prove almost as consequential—India's new determination to join the ranks of the world's top maritime powers (2). New initiatives to build out ports, develop bulk shipbuilding and repair capacity, new partnerships in the Indian Ocean, and new naval programmes (3) all portend this possibility.

To achieve its stated goals, New Delhi will have to overcome meaningful industrial and policy challenges at home. India's recent growth trajectory suggests ample capacity to do so, but it will also confront complex challenges overseas, where traditional partnerships are being upended. These changes create a significant opportunity for New Delhi, but also uncertainty.

At present, India's overall maritime presence in no way matches its economic or power profile (4). Consider this leading indicator—although India is the fifth largest economy in the world, it does not have a single port in the top 25 (5, 6). This is the legacy of India's long hesitancy to integrate its economy into global markets. As such, the Modi government's decision to create a Maritime Development Fund for port development and the bulk ship-building industry has the potential to significantly bolster the Indian economy (7).

However, this is all happening at a time of major turbulence in geopolitical affairs, much of it playing out in the maritime domain.

Opportunities and Uncertainties

First, it is necessary to understand the contemporary dynamics of maritime commerce. More than is commonly understood, this is THE story of globalisation. The advent of bulk shipping transformed global trade (8) from a system of flows of raw materials from the Global South to the centres of industrial production in the North to a world where every major economy is linked by the crisscrossing of bulk shipping across the world's oceans. It also transformed Asia, as first Hong Kong, then South Korea, and then Singapore and Japan moved to capitalise on the possibility of exporting to the West. As did, providentially, China (9). Trade grew, ship sizes grew, the Chinese economy grew, and globalisation spread. For 30 years, these things have moved together in lockstep (until interrupted by COVID-19) (10).

The global economy relies on the oceans for more than shipping and surface transport. Indeed, globalisation depends on the flow of data and finance even more than the flow of bulk shipping. These rely on the fibre-optic cables that crisscross the ocean floor. These have long been a feature of global power projection and trade, but are vastly more so now as data has revolutionised every aspect of modern commerce, society, and politics. Ninety-seven percent of the data that shapes human lives moves across undersea cables, including US$10 trillion in financial flows daily (11).

This is all well by the norms and convictions of liberal economics. However, in the world of power politics, there is a problem, because this globalised production (as well as its internal model and size) has given China a hugely outsized role in global supply chains. A role evinced by the scale of trade through its ports: compared to India's two ports in the top 60, China's ports dominate the global league tables. Shanghai, the world's largest container port, moved 49,000,000 container drops in 2023 (12). Singapore, Busan, and Rotterdam also show up in the top 10, with 39 million, 23 million, and 13 million container drops, respectively (13). Overall, China has nine of the top 20 ports in the world, vastly outscaling any other country; even the US only has one port in the top 20 (LA in 17th position, with 8.5 million drops) (14). The US and Europe are major import destinations, but their reliance on maritime flows out of Chinese ports is enormous.

This has also given China a driving logic for naval expansion—its growing fleet is now the world's largest by number of ships, though the US retains an advantage in overall tonnage. China's naval build-up has spurred or amplified growing US-China tensions, which have deepened over the past decade and also brought naval dynamics to the forefront of geopolitics.

All this is causing American policymakers to feel deep unease about the US's naval posture in Asia and its overall reliance on Chinese shipping. From unease to action: an early move by the Trump Administration has been to slap expensive port fees (up to US$1 million per ship/docking) for Chinese-owned ships entering American ports, and only somewhat less expensive fees on non-American shipping firms that have Chinese-built ships in their fleet or on their order books (15). This is essentially every major firm—Chinese shipbuilding now accounts for more than 60 percent of global orders (16). The US is developing other legislation to regenerate American domestic shipbuilding or forge partnerships with allied and other shipbuilders (17).

This is deeply uncomfortable for the US and, to a lesser degree, for Canada and Europe. As tensions between Western countries and China rise, dependence on Chinese supply chains and manufacturing flows creates a significant vulnerability. Reversing the dependence on China can go one of two routes: the very expensive option of returning manufacturing to the West or the more practical option of finding new suppliers. We will likely see some of both.

This could constitute a major opportunity for India. There is a strong appetite for new suppliers, but absent a radical change in the global supply chain model, these suppliers need to be linked by sea. India's move into the maritime domain could enable it to play an important role in supplanting Chinese supply chains.

But it could come at a time when US-China tensions heighten the risk of war at sea in the Western Pacific and perhaps the eastern reaches of the Indian Ocean, which could roil maritime commerce.

There are other uncertainties, too, from Washington's new trade policy.

The interaction between India and the US (and Europe) in the maritime domain is growing. There is the Quad arrangement, which, though it goes by several nomenclatures, is best understood as a maritime security partnership. There's an American P8 presence in Port Blair, India's Andaman-facing naval base. And there is incipient US-India cooperation in the critical realm of undersea sensing technology. From the US Navy's vantage point, India is the preferred partner for operating in the Indian Ocean to deter the growing Chinese presence there.

Given the difficulties the US will inevitably encounter in attempting to rejuvenate domestic shipbuilding, and the limits on the speed at which Japan, South Korea, or any European manufacturer can expand its capacity (plus the mounting tensions between the US and its traditional European allies), the pressure for new partnerships will grow, and India's new initiative for bulk shipbuilding could be a major beneficiary.

But there is a twist: the US appears to be moving towards reducing its reliance on global supply chains and towards restoring American manufacturing. That appears to be the underlying purpose of President Donald Trump's renewed, stronger emphasis on tariffs. Trump's tariff moves have been characterised as ill-founded and erratic, but they appear to be underwritten by an effort to return manufacturing to the US. Whether or not this effort will succeed remains to be seen, but both a shift in the US and its potential knock-on effects could reshape the maritime landscape at the moment when India is seeking to enter it.

While the effort to re-shore manufacturing concentrates on high-end efforts like advanced semiconductors, the tariff threat could quickly sweep up India. Trump has already lumped India in with Canada, Mexico, and China when talking about countries that "treat us unfairly". In his State of the Union address, for instance, Trump specifically referenced India in his discussion of unfair trade rules and his desire for reciprocity (18).

Additionally, he has a particular bugbear about the BRICS and has now twice threatened 100 percent tariffs on goods coming from the BRICS countries if they make moves toward de-dollarisation (19). While India is hardly a proponent of shifting towards a global financial system hinged around the Chinese renminbi, it has been a proponent of a more balanced system of global currency reserves. However, such subtle distinctions may be lost on a president who seemingly believes Spain is a member of the BRICS (20).

Conclusion

India's economic future surely lies at sea, and the future of globalisation will indeed be wrapped around the beam of India's maritime developments. But New Delhi will have to navigate a tricky space, where the commercial maritime world and the naval geopolitical world may move in opposing directions, with geopolitical tensions rising and increasingly playing out in the naval realm, while maritime commerce continues to operate around liberal globalisation norms. This is where the US, deeply enmeshed in maritime globalisation, is uneasily trying to extricate itself. There is a huge opportunity here, but also peril.

KEY TAKEAWAYS

India's decision to develop its maritime presence has the potential to be a key factor in transforming globalisation.

However, New Delhi will have to navigate geopolitical complexity, as the US tries to move away from the globalisation model that has characterised the last 50 years.

A naval build-up should move at pace with commercial investment, as geopolitical contest at sea is a present and building challenge.

Bruce Jones *is a senior fellow at the Brookings Institution and the author of* To Rule the Waves: How Control of the Oceans Shapes the Fate of the Superpowers *(Scribner, 2021).*

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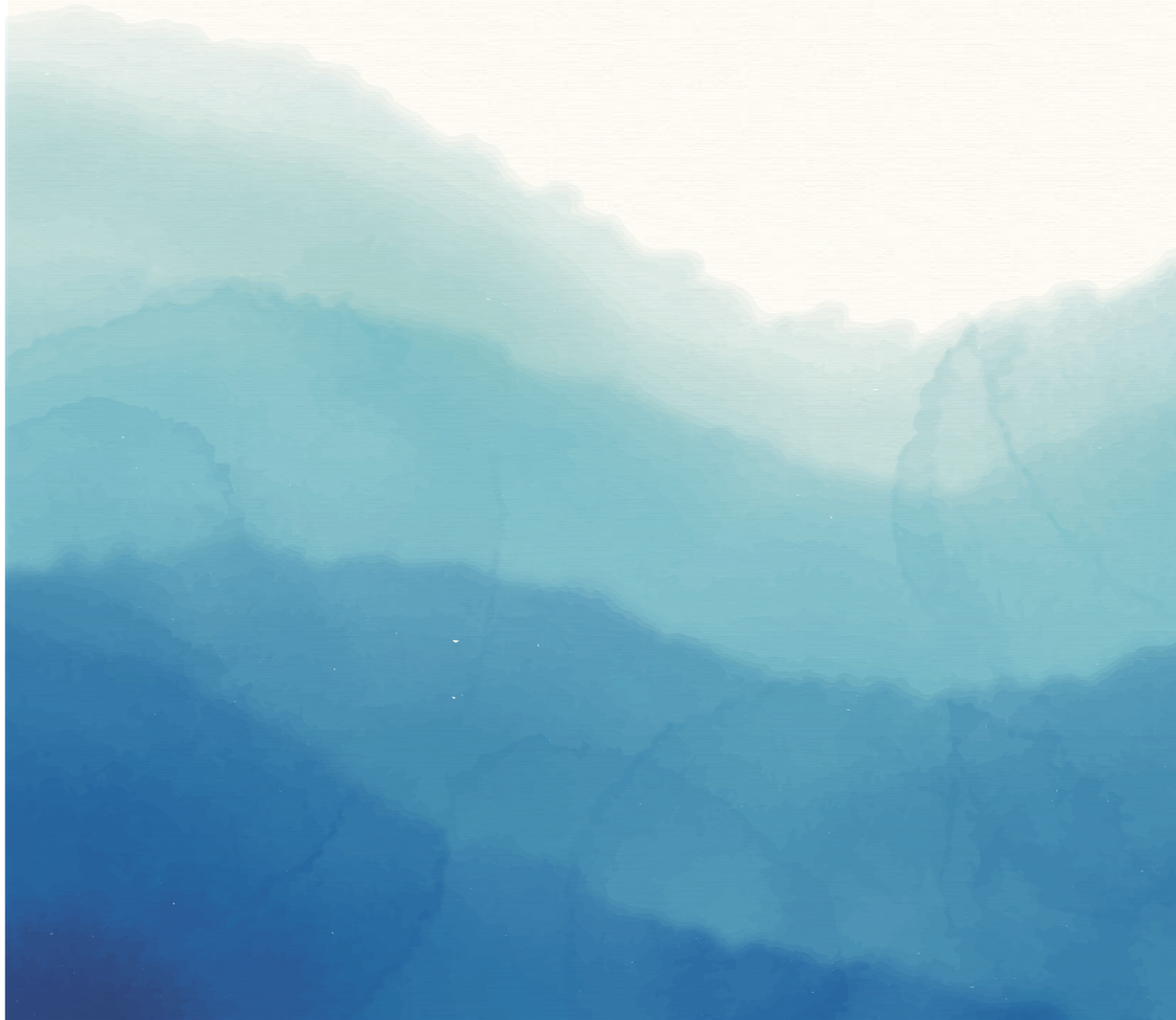
The EU and India: Common Challenges and Opportunities in Port Development

Tomasz Łukaszuk



Poland's presidency of the European Union (EU) in 2025 attaches great importance to the maritime domain concerning security and the blue economy (BE). Russia and China's illicit and aggressive policy in the waters of the Baltic Sea and the Arctic Ocean, attacking elements of the blue economy (1) and telecommunications infrastructure in 2024 and 2025, triggered the EU's reaction. The EU Commission said it "condemn[s] any deliberate destruction of Europe's critical infrastructure by Russia's shadow fleet" (2). The Commission pledged to strengthen its efforts to protect undersea infrastructure and international cooperation (3). The EU started to extend its maritime security endeavours beyond the regular cooperation of national navies in 2022 after the Russian invasion of Ukraine, bringing war to the Baltic and Black Seas after 80 years of peace. After the cooperation of the EU members as part of the EU Naval Force in the Indian Ocean through Operation Atalanta (4), the imperative of establishing regular joint naval operations in the Baltic Sea occurred in the context of the threat of Russia's naval attack and growing asymmetric threats from its shadow fleet. The process of enhancing EU naval cooperation was boosted by the creation of the post of Commissioner for Defence and Space in 2024, aimed at reinvigorating defence industries in Europe, including naval shipyards.

The EU went beyond its previous approach towards a blue economy focused on fisheries and aquaculture, launched in the form of the Common Fisheries Policy in 1982 (5). The organisation was the first to introduce the Integrated Maritime Policy in 2007 as a part of the implementation process of the provisions of the United Nations Convention on the Law of the Sea. The EU's attitude toward the blue economy changed to a more holistic and comprehensive one under the pressures of the shift in regional security conditions and the impact of extra-regional partners from the Indo-Pacific, especially India and the Association of Southeast Asian Nations (ASEAN), whose understanding of the blue economy is broader than that of the EU. It includes the security of strategic sea lines of communication (SLOCS) (6), as their role in the global supply chain is critical, transporting 80 percent of the world's seaborne oil trade (7). Another important source of their comprehensive approach is the strengthening of China's maritime power through the implementation of its Belt and Road Initiative (BRI) (8) in the form of 17 dual-use ports as mixed civilian and military infrastructural outposts at the critical chokepoints in the entire Indian Ocean basin since 2013 (9). In 2018, China started the Pearl Maritime Road Initiative in the Southwest Pacific as an extension of the BRI, investing in 19 ports in Fiji, Papua New Guinea, Samoa, and the Solomon Islands (10, 11).

China applied the same patterns in the Mediterranean and the North and Baltic Seas, where it took over (entirely or partly) or built 12 ports and container terminals in EU member states Belgium, France, Germany, Greece, Netherlands, and Spain (12). There are 1200 ports in the EU, of which 764 are major (13). In six major EU ports—Rotterdam, Antwerp, Hamburg, Bremen, Valencia, and Piraeus—China's assets range from 25 percent to 100 percent (14). In 2023, ports were responsible for 43.9 percent of the EU's exports and 51 percent of its imports. Together with the shipping industry, ports constitute a critical element of Europe's blue economy, contributing USD$162.5 billion (15). In 2024, the European Sea Ports Organisation (established in 1993) decided to initiate the European Ports Alliance as a public-private partnership under the auspices of the EU Commission to support port authorities and shipping companies to protect logistics (16). The same year, the European Parliament expressed its concern in a special report over China's military-civil fusion strategy (17). The report pointed out that China was "increasingly gaining access to and exercising influence over European critical infrastructure, such as transport infrastructure and ports, (…) and instrumentalises all levels of state and commercial power to strengthen and support the Chinese Communist Party and its armed wing, the People's Liberation Army" (18). Representatives of the EU member states called on governments and the Commission to limit China's influence on ports.

Sharing similar challenges and being aware of the 95 percent share of maritime transportation in trade, the EU and India, as strategic partners, should consider deeper cooperation in securing ports and the accompanying elements of maritime infrastructure in the Indian Ocean and European seas. Both partners are committed to pursuing a free, open, inclusive, and rules-based maritime order and addressing common security challenges (19). They could take action to create synergy in their activities in both regions. A complementarity of the efforts undertaken should be assumed to avoid the risk of being played off against each other by external actors (20). India's 'Sagarmala' strategy, adopted in 2015, and the EU's common port strategy, proposed in 2023, should serve as a common basis to develop a joint programme. The potential for joint programmes in port development is significant, based on the positive experience of EU member states in

sustainable port development cooperation with ASEAN countries (21), and should be a cause for optimism. European advanced technologies for constructing, maintaining, and securing port facilities match Sagarmala's goals of creating smart ports, developing additional transshipment terminals, and enhancing port interconnectivity (22). A first major endeavour in this context could be the EU investing in Vadhavan, India's deep-water port, to be built 150 km from Mumbai, a gateway for the EU's products imported to India, by 2029 (23). If the EU and India fail to strengthen their maritime partnerships, the potential consequences for global trade could lead to China's monopoly over SLOCs and major ports connecting both regions in the coming decades.

Conclusion

The EU and India share a common understanding of the blue economy, which is premised on the rules-based order at sea and the cooperation of all states. They also share a deep understanding of the negative impact of China's expansion in the major ports and container terminals on SLOCs, which directly affects their economic interests. Given the significance of maritime trade routes between India and the EU, the deepening of their cooperation in port development is not just important but imperative. The EU's technological capacity and experience in cooperation with other countries in the Indian Ocean Region, combined with India's Sagarmala concept of comprehensively developing ports and capital resources, create conditions for synergy.

KEY TAKEAWAYS

- China's dominance in key ports on the SLOCs between Europe and India has reached a critical level, posing a significant and mid- and long-term threat to the security of their trade cooperation.
- The EU must participate in India's Sagarmala port development programme.
- India should use its financial resources to invest in terminals and ports on the maritime routes to the EU.

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Furthering the Partnership Between the Gulf States and India in Maritime Security

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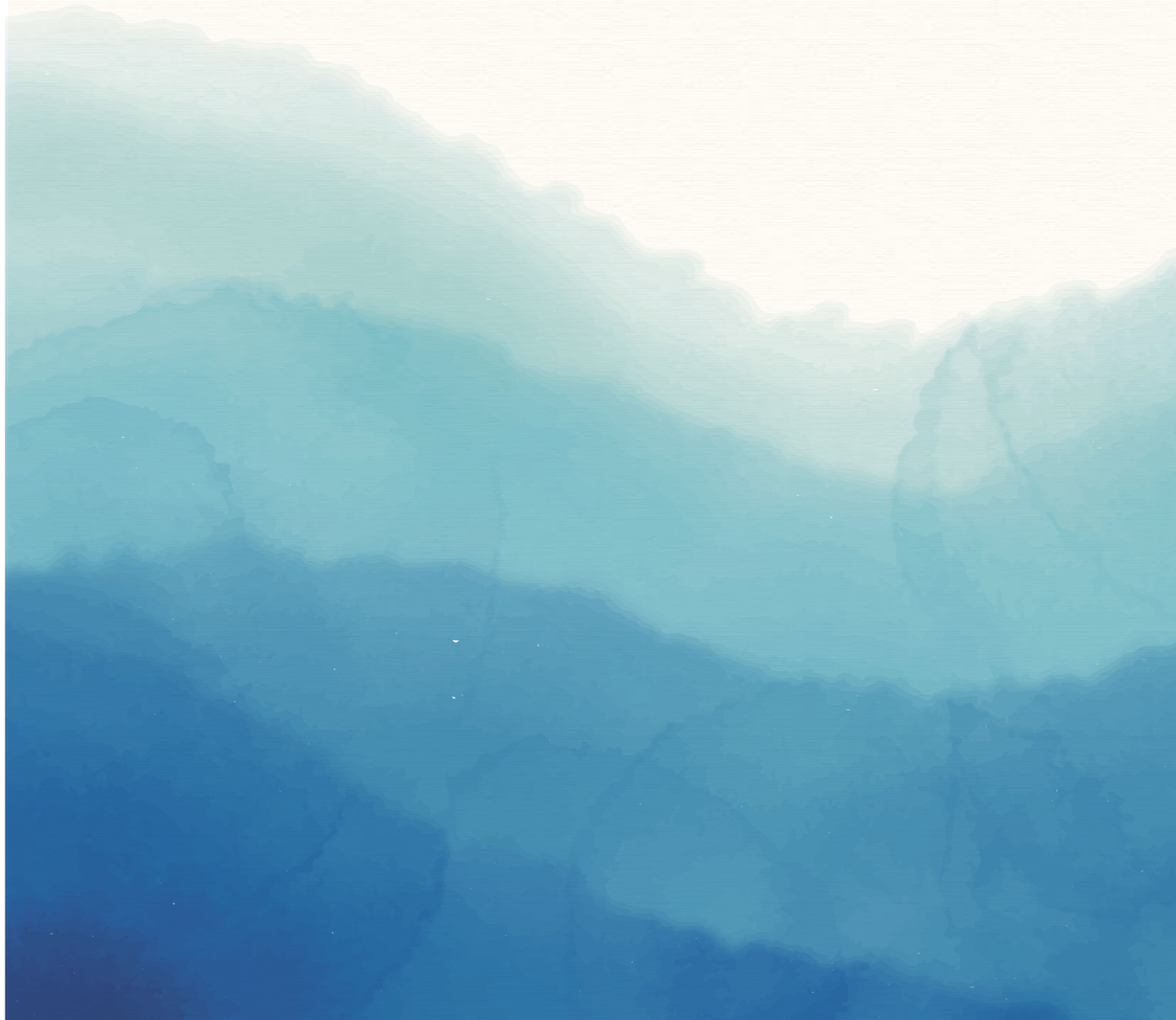

Maritime security is a vital aspect of global trade, and is particularly important to the Arab Gulf countries and India. The partnership between India and the Gulf states in this domain has seen several important developments over the past decade (2014-2024).

The Indian Ocean has been a key route for seafarers for centuries. Over different ages, particularly during the height of the Islamic Empire, India emerged as a maritime power in the region because of the strength and diversity of its economy (1). Moreover, India's strategic location and policy of treating traders well were key reasons for the prosperous trade in the region (2).

Based on these historical dimensions, India and the Gulf states have continued cooperating, including numerous visits by Indian ships to the Gulf ports, with 35 trips between 2013 and 2022 (3). These visits are significant as they enhance the efficiency and strength of the naval forces of the Gulf states. This also reflects India's interest in developing ties with the Gulf countries in the maritime field, culminating in the signing of several agreements, such as the 2016 maritime agreement between Saudi Arabia and India to cooperate on enhancing maritime security in the Arab Gulf region and the Indian Ocean (4) and the 2018 logistics agreement between Oman and India to allow the Indian naval force access to the port of Duqm. Additionally, the Indian and Gulf navies have conducted several joint exercises (5).

Importance of Regional Organisations

Another avenue of cooperation is through regional organisations, such as the Indian Ocean Rim Association (IORA), which includes 23 countries and 10 dialogue partners, two of which are Arab Gulf countries (Oman and the UAE) and two neighbouring countries (Yemen and Iran). Notably, the IORA charter stipulates three objectives of interest to India and the Gulf states—maritime safety and security, fisheries management, and disaster/crisis risk management (6).

The blue economy, women's economic empowerment, and sustainable development have also been introduced as new priorities for the IORA. However, despite their importance, achieving these priorities faces several challenges, including economic disparities among member states, which influence priority-setting, and political tensions between some countries. Additionally, financing constraints, climate change, and limited civil society participation complicate progress in these areas (7).

Another organisation for cooperation between India and the Gulf states is the Indian Ocean Naval Symposium (IONS), which includes 25 member states and nine countries as observers, including four Gulf states (Saudi Arabia, Oman, Qatar, and the UAE) and Iran. The IONS is a voluntary initiative to increase cooperation between the maritime forces of coastal states in the Indian Ocean region. As part of the mechanism, there is the exchange of information between naval forces, which enhances maritime security (8). India and the Gulf states' involvement in IORA and IONS reflects a shared interest in securing trade routes for global shipping and reaffirms the link between maritime security in the Indian Ocean and the Arabian Gulf.

India-Middle East-Europe Corridor: A New Avenue of Cooperation

The India-Middle East-Europe Corridor (IMEC) is an additional opportunity for Gulf-India cooperation in the maritime field, notable by the inclusion of maritime security in its very conception. Three pillars, already a key part of India-Gulf ties, are also important for the activation of the proposed corridor:

Seaports: The Gulf states are strategically located in the middle of the global trade routes, which has enhanced the importance of their maritime ports for their economies. This has also driven competition between the ports (9). The volume of trade between India and the Gulf Cooperation Council (GCC) countries in 2022-2023 amounted to US$184 billion, a substantial increase over 2021 levels (US$84.4 billion), and negotiations are underway between India and the Gulf countries on a free trade agreement (10).

Marine environment: A 2023 report by the GCC General Secretariat detailed the success of the Gulf states in leveraging and benefiting from their marine resources and environments. As part of their broader economic diversification strategy, Gulf states have increasingly prioritised the sustainable development of marine resources and the protection of the marine environment, yielding promising results ranging from 57.1 percent to 100 percent (11).

Maritime corridors: The Arab Gulf countries depend highly on maritime corridors for their trade with the outside world. The Strait of Hormuz is one the most important chokepoints for oil trade, with around 17 million barrels of oil—or about 20 percent of total global supply—passing through each day. Another important maritime route is the Strait of Bab al-Mandeb, the waterway that connects the Pacific and Indian Oceans, with 57,000 containers—or 10 percent of the total global trade volume—passing through it daily (12). The two corridors have also served as avenues for non-Western powers to

maintain maritime security (13) through developmental projects such as the Chinese Belt and Road Initiative (BRI) (14). Notably, India's 2015 maritime security strategy identified these two corridors as among nine critical maritime passages to protect its international trade (15).

However, the actualisation of the IMEC faces several challenges, including China's growing economic relations with the Arab Gulf countries. The volume of trade between China and Saudi Arabia reached over US$100 billion in 2023 (16). Moreover, Chinese firm Cosco has an approximately 20 percent share at the Red Sea Gateway Terminal, a Saudi company for container construction, operation and maintenance (17). Additionally, non-oil trade between China and the UAE amounted to about US$72 billion in 2022 (18). The second challenge is that, according to the corridor's plan, it will pass through the Strait of Hormuz, a strategic chokepoint controlled by Iran. Iran has repeatedly threatened to close the strait or disrupt international maritime navigation in the area, posing a significant risk to the corridor's viability (19). The third challenge lies in trade and regulatory factors. Achieving a 40 percent reduction in transport time and a 30 percent decrease in costs—as the IMEC envisions to achieve—may be overly optimistic, as success depends on the growth of global trade and a rise in the demand for Indian goods in Gulf markets (20). Additionally, there are funding challenges and the participating countries' diverse priorities. The fourth challenge is that the project is viewed as a means to achieve India's strategic objectives rather than as a partnership between countries. This stems from the fact that one of India's key objectives for this project is to counter China's economic influence, particularly the China-Pakistan Economic Corridor within the BRI, as well as China's expanding economic ties with the GCC.

The fifth challenge is the security risks faced by the corridor's regions, including terrorism. Additionally, conflicts such as those between India and Pakistan, Israel and Palestine, and Saudi Arabia and Iran, as well as the ongoing wars in Syria and Yemen, could hinder the implementation of the corridor's projects (21).

The Way Forward

While there are strong indicators of cooperation between India and the Arab Gulf countries in maritime security, there remain several obstacles to such cooperation. These include:

- Differences in threat perspectives. For India, maritime security is part of the competition with major powers, while for Arab Gulf states, it is about the balance of power with Iran;
- The Gulf states' overlapping commitments to the BRI and the IMEC;
- The Gulf states' security commitments with major Western powers in the field of maritime security;
- The extent to which the Gulf states can cope with an environmental disaster;
- The threat from global natural disasters. The Indian Ocean is the epicentre of nearly 70 percent of global natural disasters, including earthquakes and tsunamis (22).

However, despite these challenges, there are great opportunities for maritime cooperation between India and the Arab Gulf states. These include:

- Effectively tackling maritime disasters and crises by leveraging India's extensive experience in this field;
- Focusing on the blue economy as part of sustainable development priorities through meetings within the aegis of IONS and IORA;
- Establishing a Regional Security Forum for West Asian states, with the objective of enhancing maritime security cooperation and establishing a practical connection between Indian Ocean security and Arab Gulf security.

KEY TAKEAWAYS

The Indian and Gulf naval forces can conduct joint maritime exercises to strengthen operational coordination and strategic cooperation.

India's expertise in advanced maritime technologies, such as smart ships, should be leveraged to enhance and fortify the naval capabilities of Gulf states.

India can conduct specialised training programmes for Gulf states' coastal guard forces to improve maritime security and operational efficiency.

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Leveraging Learnings from Panama's Canal Expansion and Port Development for India's Coastal Policy

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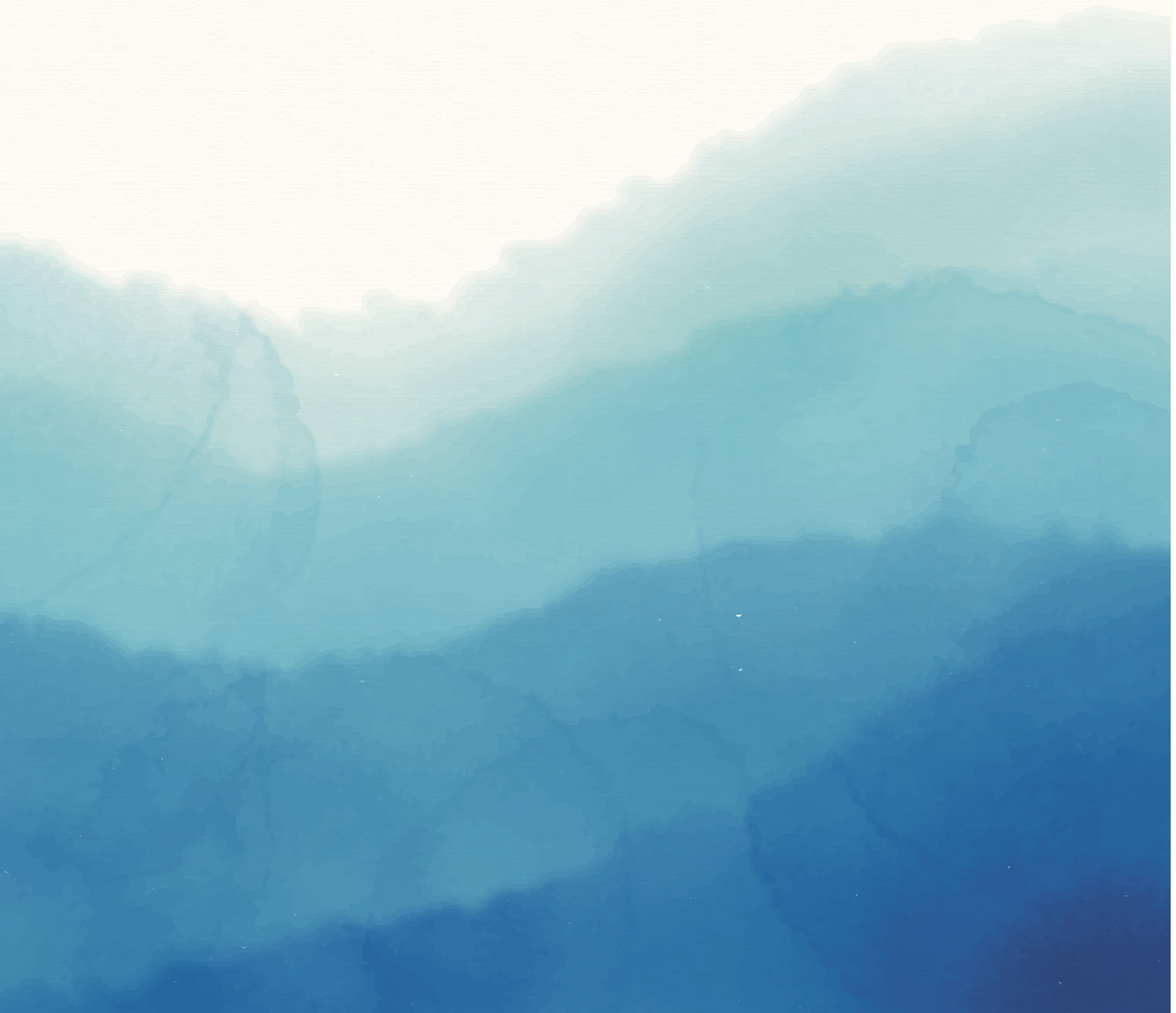

When shaping its maritime policy on coastal development, India must consider global developments that could impact both its national legislation and its commitments under international treaties related to this issue.

The recent appearance of rare fish species in areas where they are not typically found (1) suggests disruptions in the ocean's food chain. Similarly, the recent spotting of an Oarfish, a deep-sea species rarely seen at the surface, on a beach on Mexico's Pacific coast further indicates potential disruptions in marine ecosystems (2). Indeed, changes in the natural environment may be driving marine species closer to the shore. Given this, it is crucial to reassess fishing bans—potentially extending their duration in certain countries and for specific seafood products—to ensure they align with current ecological conditions. For instance, the closed season for lobster and shrimp fishing in Panama helps sustain the marine food chain, reducing the likelihood of the large marine mammals migrating to other coastal areas in search of food.

Water is a shared global resource, and its misuse or neglect along the coasts of India—or any coastline—has consequences for the rest of the world. India's vast coastline highlights the importance of water, a vital resource that is becoming increasingly scarce (3). Despite rising sea levels due to global warming, water continues circulating globally (4) from the Indian Ocean to the Arctic, through the Atlantic, and via the Panama Canal to the Pacific. Just as a small stream from a river in India flows into the sea and eventually the ocean, the water circulating and returning to India passes through the entire world. This interconnected flow highlights the importance of responsible water management and conservation efforts. Therefore, India has a responsibility to protect marine biodiversity and water quality by promoting, implementing, and enforcing strong anti-pollution policies. This includes promoting the use of non-toxic materials in the maritime industry and providing environmental management training to ship crews.

Lessons for India from Panama's Experiences

At 'Sagarmanthan: The Great Oceans Dialogue', held in New Delhi in November 2024, delegates deliberated upon India's initiatives to develop ports and promote the shipbuilding industry (5). These discussions also emphasised efforts to support coastal and island communities by advancing a self-sustaining, ocean-based economy.

The successful implementation of such efforts will require raising awareness among coastal and island communities about the importance of maintaining clean water. Many plastics and other waste materials end up in the sea due to a lack of knowledge about recycling. Moreover, awareness among coastal citizens can be further enhanced through educational programmes and beach cleanup activities.

India has ambitious port development plans (including the expansion of the Vizhinjam International Seaport in Kerala and establishing a new mega port at Vadhavan in Maharashtra) and has the capacity and workforce to achieve them. When considering the budget investments required for such port development, whether government-operated or given as concessions to private entities, Panama's experience offers valuable insights. India should carefully evaluate its approach to port ownership, ensuring that its ports remain state-controlled rather than privatised.

Panama underwent a privatisation process for two major seaports: Balboa Port on the Pacific coast and Cristóbal Port on the Atlantic coast, both connected by rail and land infrastructure (6). These concessions recently gained global attention following statements by the US president regarding China's growing influence in Panama (7). Subsequently, the BlackRock-TiL Consortium announced it will acquire CK Hutchison Holdings Limited's interests in Panama Ports Company, which operates the Balboa and Cristóbal ports (8). What lessons does Panama's experience offer India as it seeks to shape its coastal development policy and regulatory framework? Concerns over the control of the Panama Canal, particularly regarding China's alleged influence (9), underscore the importance of maintaining neutrality, security, and unrestricted access for global maritime trade. India cannot risk granting port concessions to foreign-controlled corporations that may impact critical sectors, such as maritime education, fishing regulations, environmental protection, port development, and coastal ecosystems. To safeguard its interests, India should ensure that coastal development remains independent of agreements that could lead to similar challenges in the future.

India-Panama Maritime Ties

Global oceanic changes can affect coastal regions worldwide, and India's coastline is no exception. As rising sea levels, shifting marine ecosystems, and evolving trade routes reshape the maritime landscape, nations must adapt their policies to safeguard economic and developmental interests.

In this context, India and Panama share a significant maritime connection. Many Indian nationals work on Panamanian-registered ships that are supervised by the Panama Maritime Authority. This longstanding relationship underscores the importance of collaboration between the two nations in areas such as seafarer training, shipping regulations, and sustainable maritime practices. Strengthening these ties can help both countries navigate emerging challenges in global shipping while reinforcing India's position as a key player in the international maritime sector.

By investing in technical maritime education for coastal communities, India can cultivate a highly skilled workforce, ensuring that its nationals are among the most qualified crew members on Panamanian-registered ships worldwide.

India exports a variety of products to Panama, including incense, plastic combs, and cookies, all transported as containerised cargo by sea. These goods are sold in Panama and re-exported to countries across Central and South America, further strengthening trade ties between the two nations.

Panama's recent real estate boom has led to increased land reclamation using concrete, stone, and landfills, encroaching on marine ecosystems. While these developments have contributed to economic growth, they have also had an impact on biodiversity. If similar land reclamation projects are undertaken along India's coastlines, mitigation measures such as creating artificial marine habitats and establishing breeding and relocation programmes for marine species can help minimise environmental disruption, while supporting sustainable coastal development.

Conclusion

Any port and coastal development in India should consider the following key aspects:

- Ensuring drinking water security: Safeguarding the population's right to clean drinking water by establishing and maintaining water treatment plants, thereby reducing reliance on imported bottled water.

- Marine conservation and sustainable fishing: Implementing measures to increase fish population and enforcing closed fishing seasons for marine species that require protection.

- Sustainable maritime industry: Developing policies promoting material reuse and encouraging environmentally responsible maritime practices.

- Learning from Panama's experience: Inviting professionals from the Panama Canal Administration to share their experiences and insights on the development of the coastal areas near the canal and its impact on local communities.

- International collaboration for ocean protection**:** Recognising that protecting marine ecosystems and ensuring sustainable maritime development require global cooperation. A bilateral exchange between India and Panama can provide valuable insights, particularly regarding the expansion of the Panama Canal and its impact on the maritime industry, which can benefit India's coastal development strategies.

KEY TAKEAWAYS

Ensuring a sustainable drinking water supply is a top priority when shaping policies to protect and develop India's coastal areas.

Educating island and coastal communities on water conservation, recycling, and organising beach cleanup initiatives is essential for maintaining clean marine environments.

An exchange of experiences between India and Panama can provide valuable insights into maritime sustainability, with lessons from Panama's efforts in sea protection and the expansion of the Panama Canal, as well as its impact on India's maritime industry.

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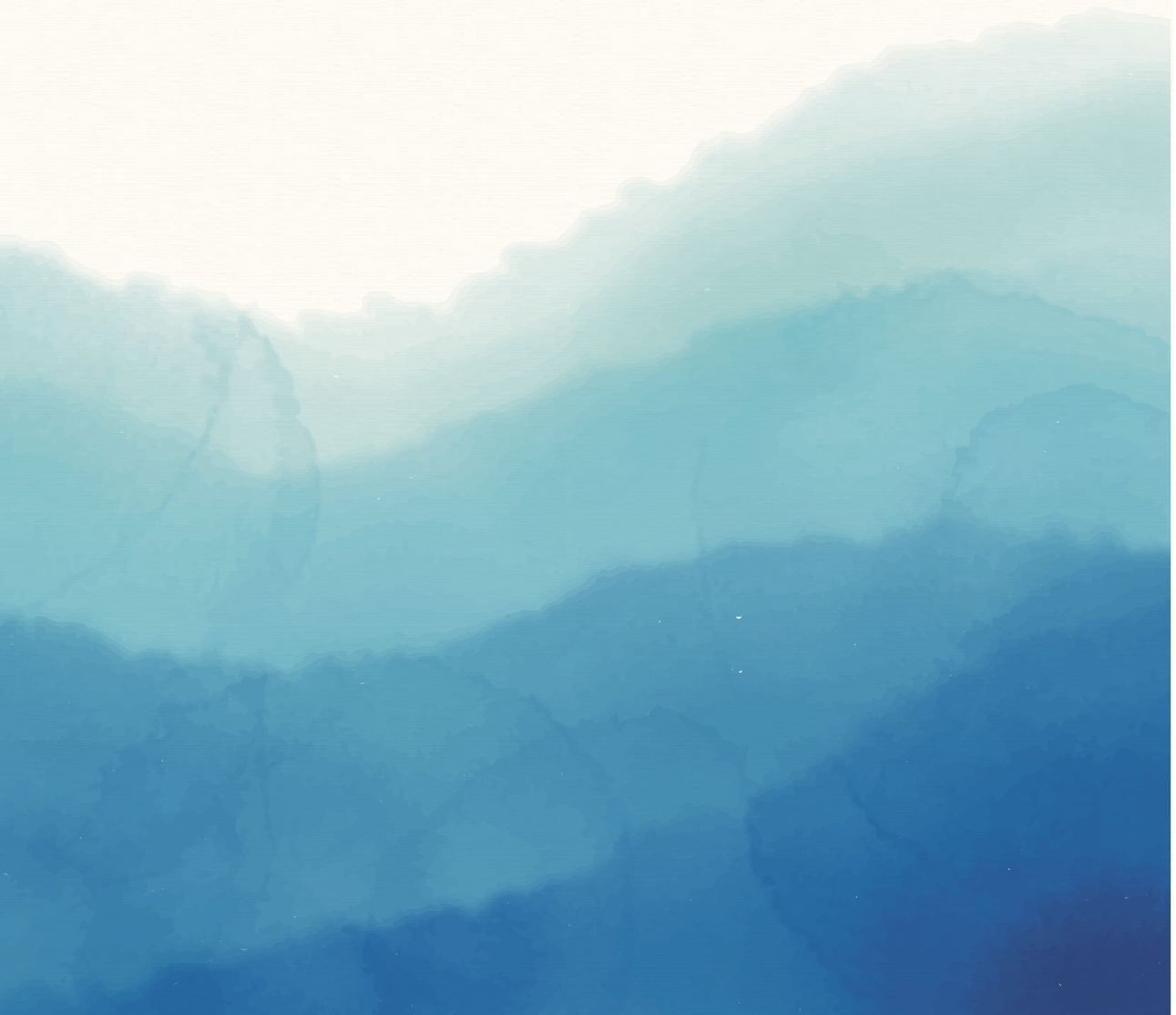
Advancing the Blue Economy in the Arctic

Mads Qvist Frederiksen



The boundaries of the Arctic region can vary depending on the criteria used to define them, but they are generally recognised as the eight Arctic states within the Arctic Circle, of which the Arctic Ocean lies at the centre. Located at the northernmost part of the planet, the Arctic region is characterised by an ocean surrounded by land rather than land surrounded by the ocean.

The Arctic is experiencing climate change more rapidly than any other region on Earth. Scientists estimate that global warming in the Arctic occurs at three times the global average rate (1). These changes are impacting the local communities in the Arctic and the global environment. Shifts in the Arctic climate contribute to rising sea levels and more extreme weather patterns, even affecting phenomena as distant as the monsoon in India (2). As the Arctic undergoes these profound shifts, its vast natural resources and emerging maritime routes present challenges and opportunities. A sustainable blue economy, centred on responsible resource management, renewable energy, and resilient infrastructure, is essential to ensure the Arctic remains a vital contributor to global stability and prosperity.

The People's Arctic

The ocean is and always has been important to the people of the Arctic. The region is home to over four million inhabitants, around 10 percent of whom are Indigenous (3). Thousands of years ago, Arctic peoples migrated over the ice to explore new hunting grounds (4). Vikings from Norway would take their ships to Iceland, Greenland, and North America to explore new trading opportunities (5). Fish bones originating from the northern part of Norway have been found in archaeological excavations in Germany, thus showing that trade and the ocean have always been closely connected (6).

Today, the region’s main exports also come from the ocean. Be it seafood, which accounts for more than 95 percent of Greenland's exports, or energy exported from outside Hammerfest in Norway, these goods will be transported by sea by ships navigating the Arctic waters (7). The ocean remains as crucial as ever for the people of the Arctic, serving as a lifeline for their economy and culture. As climate change accelerates, the region faces new challenges with melting ice opening shipping routes and shifting resources.

Connectivity and Climate

The current situation in the Arctic has been complicated by the experience of recent years, which has shown that companies and states can no longer rely on

a single logistics route. Humankind has gone from planning ‘just in time’ to ‘just in case’. For instance, when a ship was stuck in the Suez Canal, global maritime traffic had to navigate new routes (8). Piracy has also meant that shipowners face increased shipping costs for transits made through risk-prone regions such as the Gulf of Aden and the Red Sea (9, 10). Further, the 2024 drought in Panama due to climate change meant fewer ships could sail through the Panama Canal (11).

Consequently, climate change has created new strategic priorities for governments. In the Arctic context, for instance, the Russian government has invested heavily on infrastructure around the Northern Sea Route, which is poised to reduce the transit time between Asia and Northern Europe (12). Similarly, the Canadian government is exploring the opportunities presented by the North-West Passage (13, 14). The greatest potential, however, likely lies in developing the Transpolar Shipping Route, which would connect the Pacific and Atlantic Oceans and represent a shipping route with shorter transit times than the Northern Sea Route (15). As global warming progresses, it is expected that, for the first time in human history, the Central Arctic Ocean will become navigable and ice-free during the summer months, presenting new opportunities for maritime transport and trade (16).

The Arctic’s Bounty

As new shipping routes become accessible, the Arctic's vast natural resources have the potential to play a significant role in advancing the blue economy, particularly in the areas of energy and food security. The region's food resources may contribute to addressing the needs of an increasingly urbanised population in Asia and Africa. With more protein-rich fish being sold and new brands utilising kelp and seaweed (like Norway's Lofoten Seaweed), the Arctic has the potential to play a key role in feeding the world (17, 18). Additionally, there are several innovations that maximise the potential of the blue economy. What was once considered waste is now being transformed into valuable products. For instance, Icelandic firm Kerecis has turned cod skin from the Arctic into a specialised human tissue regeneration product (19).

There is also immense potential for energy derivation in the Arctic. Decades ago, whalers would collect whale blubber to light up the streetlamps in major cities (20). As the years progressed, oil and gas from the Arctic have supported global industrial development (21). In the future, new energy exports from the Arctic are expected, partly because the region is home to some remarkable renewable energy solutions. For example, in Iceland, geothermal energy harnesses the planet's heat (22), while hydropower in Greenland is generated from melting ice waters. Additionally, wind turbines—both onshore and offshore—will take advantage of the region's strong northern winds (23, 24). All this renewable energy will be used in the Arctic and will likely also be transported to markets in the south via the ocean. This energy could include hydrogen, ammonia or e-methanol, which could then be used to fuel green shipping (25).

Finally, certain companies in the Arctic can help the fishing industry in developing countries. For example, Kongsberg Satellite Services (KSAT) from Tromsø in Norway has assisted with Blue Justice, a global initiative that seeks to mitigate illegal, unreported and unregulated (IUU) fishing through the use of space technology (26). Illegal fishing devastates coastal communities, threatens ecosystems, and puts the global food supply at risk, while also supporting organised crime (27). However, tracking and identifying these “dark vessels” is difficult since they deactivate their automatic identification system (28). As such, initiatives combining northern expertise in satellite technology with advanced data processing and analysis will need partners with experience in vessel detection to combat IUU fishing.

Leading the Way Forward: Navigating Challenges and Opportunities

In times of change, working together and building strong partnerships is important. The blue economy presents various areas for potential cooperation. Be it seafood and bio-innovation, energy in the form of oil or hydrogen, or new companies solving old problems, it will be possible only through cross-border partnerships and collaboration.

As global challenges demand collective solutions, fostering cooperation in regions like the Arctic becomes even more critical. For instance, the Arctic Economic Council, an international business membership organisation, brings together members from 10 countries with a shared interest in the High North (29). It was created a decade ago by visionary leaders who saw the Arctic region’s increasing importance. Today, the organisation facilitates policy advocacy, networking, and communication about the little-known region, striving to build partnerships that benefit the Arctic's people.

However, the Arctic region has three major challenges that specifically require global partners. The first major obstacle to sustainable economic development in the Arctic is insufficient infrastructure such as deep-sea ports or subsea fibre optic cables connecting the unconnected in the north to bridge the digital divide (30, 31). It is necessary to develop the region's physical and online infrastructure to unlock the opportunities in the blue economy in the north (32). This presents the next problem. Although the Arctic region is vast, its population is relatively small. This presents a challenge for the economy of scale. In that context, the

region needs external investments to supplement local investments. The blue economy presents the most interesting opportunities since its resources are typically renewable and plentiful. For example, the European Union (EU) is facilitating the work of Arctic Reflections to preserve Arctic Sea ice through BlueInvest, an EU-led platform for investments and innovation in the blue economy (33).

Finally, the third and most significant challenge facing growth in the Arctic blue economy is the lack of skilled people to work in the growing industries in the region. Companies as well as the public sector are constantly exploring new ways not only to attract but also to retain people in the Arctic. Some companies are trying to implement artificial intelligence models or robots, but this will solve only some challenges. However, there is a need for more people to move north and help maximise the region's potential. Over the years, the Arctic region has experienced outmigration combined with globally declining birth rates in the West (34). Therefore, it is crucial to find a way for people with the right skills and competencies to move to the High North and contribute to its blue growth.

Conclusion

To realise the blue economy's potential in the Arctic, it is important to focus on infrastructure, people, and investment. Expanding infrastructure can improve maritime trade and transport, while strategic investments in renewable energy and sustainable fisheries can strengthen the economy and protect the environment. Collaboration is crucial to fully unlock the Arctic's potential as a key player in the global blue economy. Strong global partnerships—both across the North and with the South—are needed. The ocean serves as a vital connector between nations and a platform for sustainable economic growth. However, success depends on seizing economic opportunities as well as investing in infrastructure and, most crucially, in people.

KEY TAKEAWAYS

- The Arctic region has plenty of opportunities within the blue economy, critical raw materials, and energy.
- The barriers to sustainable economic development are investments, sufficient infrastructure, and enough skilled workforce.
- The Arctic is undergoing massive climate and geopolitical changes, but the people living there are still the key importance.

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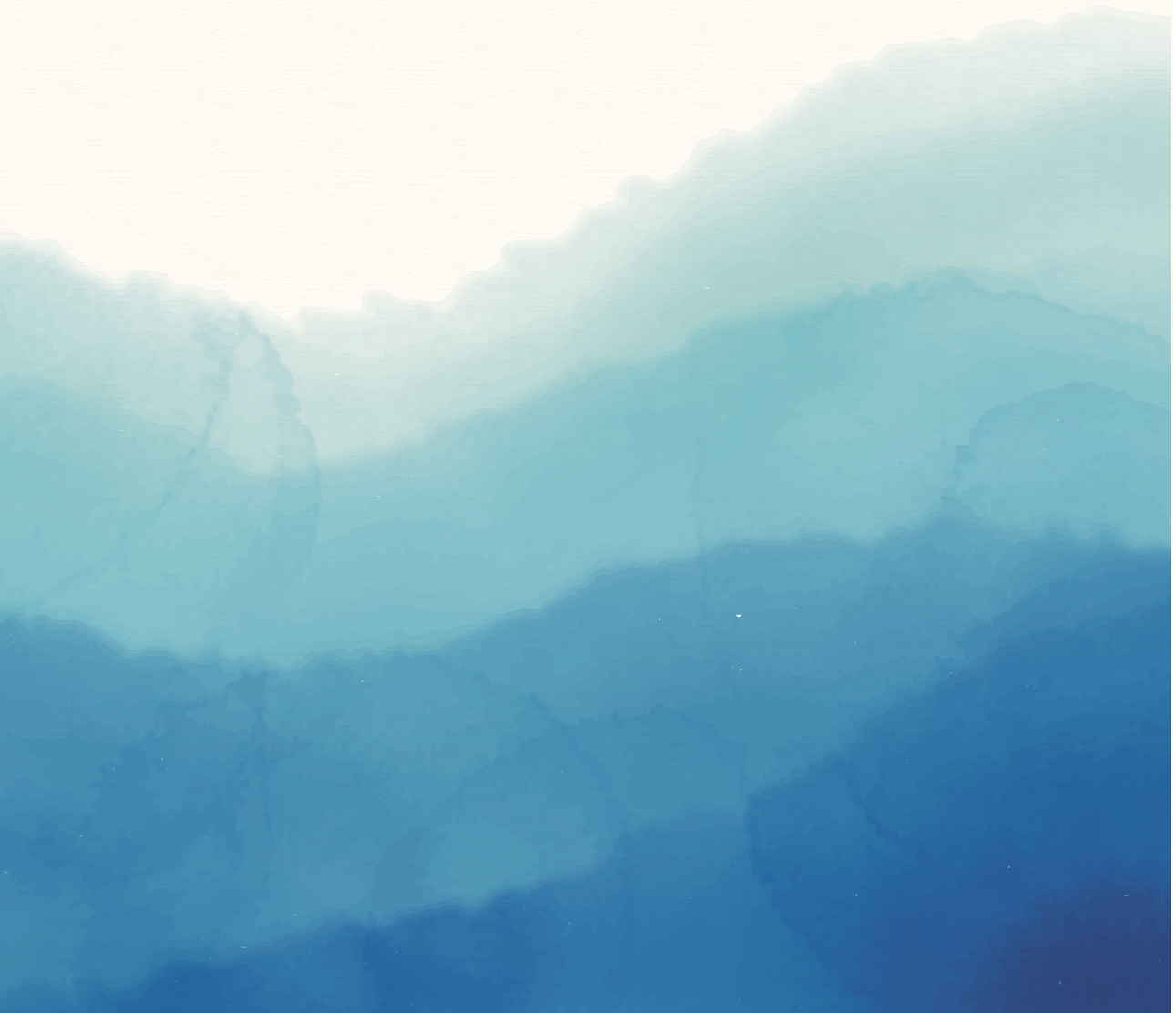
Smart Ports, Smarter Trade

Erin Watson



The world's busiest ports once relied on human labour, but now they run on artificial intelligence (AI). The largest seaport in Europe, the Port of Rotterdam, is at the forefront of adopting innovative technologies. Beyond traditional port activities such as ships and containers, the "digital port" integrates AI-powered systems such as vessel tracking systems, drones, and virtual energy systems, all of which contribute to the efficiency, sustainability, and security of port operations (1).

These systems help manage port operations more effectively and efficiently. AI-powered automation has enhanced container handling, ship berthing, and cargo tracking (2). Rotterdam is just one example of how AI is changing maritime logistics. Major ports worldwide are embracing this new era of digitisation. The world's second-busiest port, the Port of Singapore, is developing a communication tool, digitalport@SG (3), to use AI data analysis to assist with ship docking.

While technology offers excellent benefits, it also gives rise to new challenges. With digitisation, ports are becoming vulnerable to cyber threats. In 2023, the Port of Los Angeles witnessed 60 million cyberattacks per month (4). Automation also threatens labour jobs, such as dockworkers, raising workforce concerns in an often highly unionised industry. As ports lean further into adopting advanced technologies, the question remains—will this technology eliminate inefficiencies or create new dependencies?

As the world operates on commerce and trade, effective port operations play an essential role in international politics. Ports that embrace new technologies will stay ahead while others slowly become irrelevant. This shift to automation is not just about efficiency but also about shaping global trade patterns, strengthening national security, and gaining a competitive edge. With the US and China locked in a race for AI dominance (5), smart ports are emerging as the next battleground in their global rivalry.

From Chips to Ports: The US-China AI Race

The rivalry between the US and China has moved beyond trade tariffs; now, AI is the new playground for the two powers. Under former President Joe Biden, the US introduced the 'Small Yard, High Fence' policy to ban the export

of advanced AI chips and semiconductor manufacturing technology to China (6). The policy proved lenient as China was able to develop its AI chatbot 'DeepSeek' and challenge ChatGPT without using any advanced technology. Under President Donald Trump, AI trade restrictions are expected to expand beyond semiconductor exports. It is expected to include stricter cloud computing access and research collaborations, which will further complicate China's AI advancements. This AI race can also be observed in maritime logistics, where both countries are constantly modernising their ports using AI-driven automation to improve efficiency in port operations.

China is positioning itself as a leader in port automation by integrating AI-driven automation and 5G technologies in its largest ports. The Guangzhou, Qingdao, Ningbo-Zhoushan, and Hubei ports are the leading AI-driven automation systems in the world (7). China has also embedded DeepSeek in its smart ports. DeepSeek assists port operations in security, cargo scanning, gantry cranes, and AI-powered gate systems, among others (8). China has embedded automation not only in its domestic ports but also in overseas ports such as the Djibouti and Chancay ports (9). China has successfully modernised and automated the Doraleh Multi-Purpose Port in Djibouti (10). The port has increased the efficiency of vessel operations, reduced ship berthing time, and modernised loading and unloading methods. This highlights China's priority to integrate AI and automation in its domestic and overseas ports, which will lead to stiff competition in global maritime logistics.

The US is not far behind China in integrating AI in its ports. For instance, the Port of Los Angeles has rolled out its 'Port Optimizer' initiative, which uses sensor data and predictive analysis to improve scheduling and coordination of container loading and unloading (11). The Port of Los Angeles also uses AI-automated trucks and cranes to transport cargo. While AI helps tackle inefficiencies, it also introduces policy and labour challenges. Labour resistance remains one of the biggest hurdles in the race to smart ports for the US. In October 2024, 25,000 workers went on strike over two key issues: wages and automation (12). The protesting dockworkers argued that AI-driven automation will lead to mass job losses. The strike disrupted supply chains across the US, with a cost estimate of US$4.5 billion per day (13). This dynamic plays out differently in China, where modernisation and automation are state-driven with little to no resistance compared to the US, where modernisation faces a delicate balance between efficiency and labour rights.

As China and the US race ahead in AI-driven port dominance, other nations, including India and Australia, are making strategic investments to secure their own maritime futures. While they do not yet rival the sophistication of Guangzhou or Los Angeles, they recognise that smart ports are no longer optional, but are essential to economic security.

India and Australia: Catching the Wave

As smart ports start to reshape maritime logistics, India and Australia are catching up to their American and Chinese counterparts. With its Maritime Vision (MIV) 2030 and the ambitious India-Middle East-Europe Economic Corridor (IMEC), India is developing infrastructure to modernise its ports (14). The Indian Maritime sector has made significant progress under MIV. Major port capacity increased from 1598 million metric tonnes per annum (MMTPA) in 2022 to 1630 MMTPA in 2024. At the same time, Australia is investing in automation technology to integrate into its ports to strengthen Indo-Pacific resilience. Both nations deem smart ports critical to their respective economic and geopolitical futures, but face challenges in adopting the technology.

India is on the road to modernising its port infrastructure. It has identified the Jawaharlal Nehru Port Trust (JNPT) to develop into a fully smart port (15). JNPT is the largest container port in India and a critical part of the IMEC. Integrating Internet of Things (IoT), AI, and 5G technologies in the port will not only enhance efficiency in port operations but also help develop infrastructure to support IMEC operations in the future. To tackle the cybersecurity threats facing smart ports, the Indian Institute of Technology Kanpur has partnered with the Indian Ports Association to develop a cybersecurity infrastructure for smart ports (16). India's port modernisation relies on public-private partnerships, which can slow down the implementation process due to regulatory and investment policies. While IMEC is still at a nascent stage, it presents India with an opportunity to invest and align its ports with global best practices by integrating AI and digital connectivity in other significant ports such as Mundra, Kandla, and Mumbai.

Australia is rapidly embracing AI and automation in its ports. The need for Australia to digitise its ports stems not only from the need to enhance the efficiency of port operations but also from the need to protect its marine ecosystems and stay competitive in global maritime logistics. An excellent case study of Australia's port automation is the Victoria International Container

Terminal (VICT) in Melbourne (17). VICT has achieved full automation and is one of the most automated container terminals globally. The terminal operates automated cranes, stacking systems, and a predictive logistics model to reduce port congestion and optimise cargo flow. Beyond VICT, Australia is also digitising other terminals and ports, such as Port Adelaide. Port Adelaide, South Australia's largest port, is working with Complexica to integrate AI-driven automation in the port (18). The main focus of this partnership is automating and optimising the container movement efficiently and effectively to smoothen port operations. However, these smart ports face the challenge of cybersecurity risks. In 2022, supply chains in Australian ports were disrupted by a cyberattack on DP World, which led to the halting of more than 30,000 containers (19). To mitigate these risks, Australian ports must invest heavily in building cybersecurity infrastructure.

Australia and India can effectively cooperate in port development. Cooperation can be achieved through a multi-tiered approach, encompassing government-to-government engagement and partnership between research institutions. The Australia-India Infrastructure Forum is an excellent platform for collaboration in port development for both countries (20).

Conclusion

Smart ports are quietly shaping the future of global trade. Ports that are able to integrate upcoming technologies will not only improve efficiency but also gain a strategic edge in global maritime logistics. China is gradually expanding its smart port network while the US navigates the debate of automation and labour rights, and India and Australia work to modernise their maritime infrastructure.

However, digitisation and automation come with their own set of challenges. As smart ports become highly interconnected and data-driven, they become prime targets for cyber threats, while increased automation raises concerns over labour rights and job security. To remain competitive in the evolving landscape of global trade, nations must navigate these complexities carefully, balancing innovation with security and economic stability.

KEY TAKEAWAYS

Ports must rapidly integrate AI, IoT, and 5G to enhance efficiency, reduce congestion, and maintain competitiveness in global trade. Automation in cargo handling, vessel tracking, and logistics is no longer optional, but essential for relevance. Nations that fail to modernise risk becoming obsolete in global supply chains.

The US-China AI rivalry is shaping the future of smart ports, with China aggressively automating domestic and overseas ports while the US faces labour resistance and policy hurdles. Policymakers and industry leaders must anticipate disruptions and align strategies to protect economic and security interests.

As ports become increasingly digitised, cyber threats and regulatory challenges will escalate. Governments and businesses must invest in robust cybersecurity infrastructure, streamline regulations for digital adoption, and address labour concerns through workforce reskilling to ensure sustainable and secure port modernisation.

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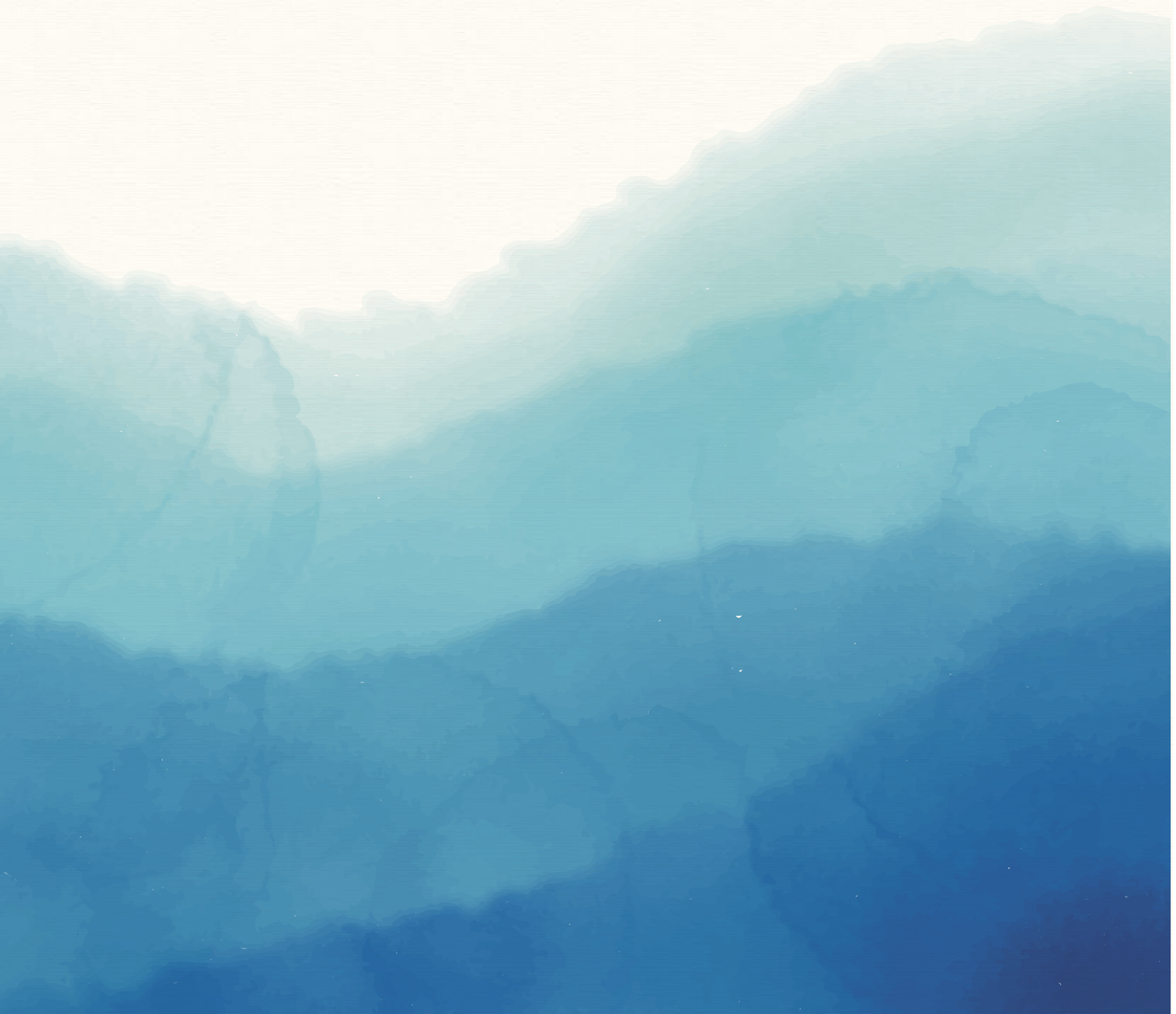
Section II

Blue Growth: Partnerships for Progress

The Promise of Blue Growth

Nadeem Nazurally



Oceans are pivotal to global trade, economic development, and environmental climate regulation. For island nations like Mauritius, blue growth presents a unique opportunity to balance economic expansion with marine conservation. Mauritius has positioned itself as a regional leader in blue economy initiatives, with several ongoing efforts in coral restoration, sustainable fisheries, aquaculture, and marine biodiversity conservation. The country showcases how island states can harness the ocean's potential while safeguarding marine ecosystems through effective collaboration and technological advancements.

The ocean economy is central to global prosperity, providing livelihoods for millions while facilitating 90 percent of international trade (1). However, challenges such as climate change, overfishing, and pollution threaten the sustainability of marine resources (2). Blue growth refers to the sustainable use of ocean resources for economic development while maintaining the health of marine ecosystems. It encompasses industries such as fisheries, aquaculture, maritime transport, renewable energy, and marine biotechnology, aiming to balance economic benefits with environmental conservation and social well-being. Island nations like Mauritius, heavily reliant on their coastal and marine environments, must adopt innovative and inclusive strategies to navigate these challenges (3).

Mauritius: A Model for Sustainable Blue Growth

Mauritius has long recognised the ocean's significance to its economic and ecological landscape. As an island nation in the Indian Ocean, its economy is deeply intertwined with fisheries, tourism, and marine biodiversity (4). Mauritius has embraced a multi-stakeholder approach to sustain these sectors, integrating science, policy, and community engagement. Notable efforts include coral restoration initiatives, sustainable aquaculture practices, and marine protected areas (5).

- **Strategic partnerships: coral restoration and marine biodiversity conservation**

Through collaborations with non-governmental organisations, such as EcoMode Society, and academia, Mauritius has developed innovative coral restoration techniques. The humanitarian coral restoration project funded by the International Union for Conservation of Nature under Tech for Nature

exemplifies how public-private partnerships can regenerate degraded reefs, enhance fish populations, and support sustainable tourism. This initiative, coupled with seagrass regeneration efforts, strengthens marine resilience against climate change (6).

- **Sustainable fisheries and aquaculture**

Mauritius faces challenges in artisanal fisheries, including resource depletion and economic instability for fishers (7). The socioeconomic status of artisanal fisheries underscores the need for policy interventions. Key measures include implementing co-management frameworks where fishers participate in decision-making and introducing alternative livelihood programmes such as seaweed farming and sustainable aquaculture to reduce dependency on overexploited fish stocks. In response, Mauritius has promoted sustainable aquaculture, integrating Internet of Things (IoT) technologies to optimise shrimp farming in freshwater environments. These advancements, supported by partnerships with private sector entities and academic institutions, enhance productivity while minimising environmental impact. IoT-based water quality monitoring systems track parameters such as temperature, pH, and dissolved oxygen in real-time, ensuring optimal conditions for shrimp growth while reducing resource waste. Additionally, automated feeding systems improve efficiency and minimise feed loss, enhancing sustainability. Another notable public-private partnership is the collaboration between the University of Mauritius and Born to Fly Ltd., which focuses on coral restoration.

- **Capacity building and knowledge exchange**

Knowledge-sharing platforms and training programmes are crucial in blue economy development (8). Training local fishers on seaweed farming and raft construction demonstrates the importance of empowering communities with sustainable livelihood alternatives. For instance, a series of training sessions across Mauritius has equipped fishers with practical skills in seaweed farming and raft construction, fostering economic resilience. Furthermore, research collaborations, such as the partnership between the University of Mauritius and Japan's Hokkaido University, facilitated knowledge exchange in fisheries management and marine conservation.

- **Policy frameworks and regional cooperation**

Mauritius actively participates in regional and international blue economy discussions (9). The country's involvement in 'Sagarmanthan: The Great Oceans Dialogue' underscores its commitment to shaping maritime policies. Additionally, Mauritius engages in the Indian Ocean Rim Association's blue economy initiatives, which focus on sustainable fisheries, maritime safety, and marine spatial planning. The country is also a signatory to the African Union's Blue Economy Strategy (10), which emphasises marine resource management, climate resilience, and regional cooperation to promote sustainable ocean economies. Through these frameworks, Mauritius strengthens ocean governance, enhances regional security, and advances sustainable blue growth.

Conclusion: A Collaborative Future for Blue Growth

The success of Mauritius' blue economy hinges on sustained partnerships and strategic investments in marine research, conservation, and innovation. By leveraging interdisciplinary collaboration, technological advancements, and policy-driven approaches, Mauritius can be a model for other island nations navigating the blue growth paradigm. The lessons drawn from its initiatives can contribute to shaping global discourse on sustainable ocean economies, reinforcing the importance of inclusive, resilient, and forward-thinking marine policies.

KEY TAKEAWAYS

Collaboration fuels blue growth: Partnerships between governments, academia, and the private sector drive sustainable ocean economies.

Innovation ensures sustainability: IoT-based aquaculture and smart fisheries management enhance marine resource conservation.

Policy shapes ocean governance: Regional cooperation and strategic frameworks secure long-term blue economy success.

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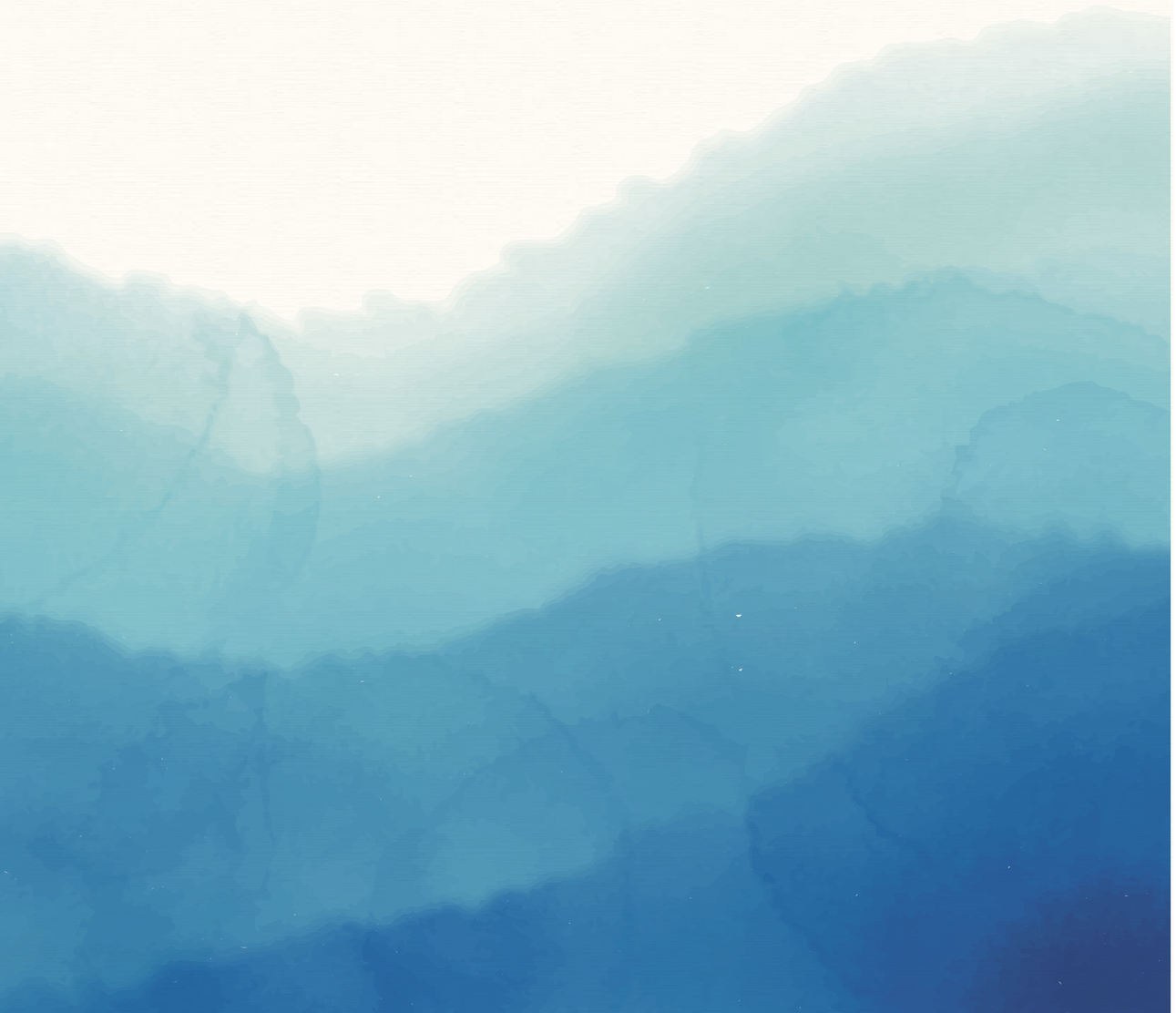
The Need to Go Green: Promoting the Blue Economy in Asia

Juita Mohamad



According to a 2023 estimate, global CO_2 emissions will increase by 410 million tonnes, with more than 65 percent originating from coal (1). Given current climate-related issues, it is imperative to keep global warming within the 2°C mark (2). Trends in Asia suggest that even for smaller countries that emit less carbon, emissions will continue to rise over the next few years if left unchecked (3).

India has set 2070 as its net-zero carbon emissions target (4), while smaller countries in its neighbourhood, such as Malaysia, Singapore, Thailand, Vietnam, and the Philippines, have set 2050 as their target year for net-zero emissions (5). Asian economies must introduce mechanisms to entice and incentivise consumers, producers, and firms to shift towards green energy to curb carbon emissions. These incentives could include green technology, green energy financing, and green investment tax allowances and exemptions. Such incentives need to be backed by an ample supply of renewable energy so that Asia's decarbonisation journey can proceed smoothly.

While countries can work independently to develop a green agenda, cooperation among like-minded states in the region can encourage a pooling of resources to the advantage of all member countries. Asian countries have a long history of cooperation, especially amid rising protectionism and global fragmentation. Indeed, regional cooperation can help address challenges member countries face while fostering growth in the region (6). This is particularly important in the maritime space, as strong regional collaboration can help ensure safe, secure, and clean seas, fostering trade and economic growth among member states. As the blue economy has the potential to develop economies in an environmentally conscious manner, regional cooperation in this area can lead to climate change mitigation, biodiversity preservation, and disaster preparedness (7).

A Rising Global South

Presently, an emerging and developing Asia is on the rise in terms of economic growth and prospects (8). Indeed, worldwide, the real GDP growth rate of advanced economies has been low over the last decade compared to that of Global South countries (9). While advanced economies are projected to experience 1.8 percent annual real GDP growth in 2025, emerging and developing economies are expected to grow by 4.2 percent (10). In terms

of the blue economy, trade in the Global South has increased significantly; between 2021 and 2023, fish exports increased by 43 percent, reaching US$19 billion, while processed fish exports increased by 89 percent (11).

With a substantial youth population, relatively ample resources, and digitisation and technological advancements, the Global South's rise is inevitable (12). Based on these factors, six Global South countries are projected to rank among the world's top 10 economies by 2050 (see Table 1) (13).

Table 1: Top 10 Countries by GDP Ranking (2016 PPP value and 2050 projections)

Ranking	2016 GDP at PPP (in constant 2016 US$bn)	Projected 2050 GDP at PPP
1	China: 21269	China: 58499
2	US: 18562	India: 44128
3	India: 8721	US: 34102
4	Japan: 4932	Indonesia: 10502
5	Germany: 3979	Brazil:7540
6	Russia: 3745	Russia: 7131
7	Brazil: 3135	Mexico: 6863
8	Indonesia: 3028	Japan: 6779
9	UK: 2788	Germany: 6138
10	France: 2737	UK: 5369

Source: *Author's analysis based on PwC's 2017 report (14).*

Given these projections and the expected rise of the Global South, the governance of trade and cooperation must be reformed. As the balance of power shifts and investment flows are reshaped, new avenues of engagement are needed. Global South countries can now highlight their priorities regarding trade, investments, and conservation. If such priorities are clearly communicated among regional and external partners, cooperation can occur through various forms, such as technical cooperation and best practices, conservation activities, or binding agreements.

India, Malaysia, and several other Asian countries are parties to various modes of cooperation aimed at mitigating climate change and promoting closer trade relations in the region, thereby addressing supply chain issues and global economic and geopolitical instability (15). In addition to binding free trade agreements (FTAs) such as the Comprehensive and Progressive Agreement for Trans-Pacific Partnership, the Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area, the Malaysia-Korea Free Trade Agreement and the Regional Comprehensive Economic Partnership, there are several non-binding cooperation mechanisms. Table 2 highlights several key active mechanisms in Asia with green components.

Table 2: Asian Non-Binding Cooperation Mechanisms with Green Components

Name	Members	Details	Commencement Date
ASEAN Plan of Action for Energy Cooperation (APAEC) 2016–2025	ASEAN member countries (Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam)	It promotes the transition to renewable energy and aims for a 23% renewable energy share in the region's total energy mix by 2025.	2016
ASEAN Taxonomy for Sustainable Finance	ASEAN member countries (Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam)	It establishes a classification system for green and sustainable investments.	2021
ASEAN Smart Cities Network (ASCN)	ASEAN member countries (Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam)	It comprises a network of 26 smart cities working towards sustainable urban development.	2018
Asia-Pacific Green Deal for Business	Members of the ESCAP Sustainable Business Network	It advocates for green energy, green infrastructure and logistics, green finance and green innovation.	2022
Sydney APEC Leaders' Declaration on Climate Change, Energy Security and Clean Development	Australia, Brunei, Canada, Chile, China, Hong Kong, Indonesia, Japan, South Korea, Malaysia, Mexico, New Zealand, Papua New Guinea, Peru, the Philippines, Russia, Singapore, Chinese Taipei, Thailand, and the US	Focus areas of cooperation include low and zero-emission energy sources and technologies.	2007

Source: *Collated by the author from various sources.*

Countries in the Global South need to establish their own regional cooperation mechanisms on green development and blue growth if they are serious about achieving net carbon emissions in the medium term. To integrate sustainability into economic frameworks, member countries must identify priorities in their regional green and blue development agendas.

Sharing of technology and innovation is needed. Studies have shown that research and development expenditure was associated with reduced carbon emissions in the US, China, and 15 European countries between 1990-2013 (16). It was also found that technology and innovation are more effective in reducing carbon emissions than renewable energy for high-emission sectors. An example of an existing cooperation network is the International Energy Agency's Renewable Energy Technology Collaboration Programme (17).

Emphasising conservation and tapping into indigenous knowledge is essential. Asian communities have long contributed to liberalising trade and investment activities. Similar dedicated efforts to conserve marine wildlife and its habitat could curb the destruction of marine life. The maritime trade sector, fishing, and transportation account for about 3 percent of total greenhouse gas emissions (18). As such, members need to cooperate to eliminate carbon emissions within this sector by leveraging the traditional indigenous knowledge of coastal communities while preserving maritime ecosystems such as those in Micronesia, Belize, and Kiribati (19).

Engaging for technical assistance and best practices is necessary. Global South countries can partner to provide technical assistance to one another and engage with developed countries in terms of training and best practices where applicable. Training and sharing of best practices are important activities in building trust among Global South partners and developed partners. Countries can learn and share new and emerging technologies and innovations to monitor and reduce carbon emissions through various working groups. An example of such an innovation is the FastRigs system, which can calculate the wind availability of all ships in different trade routes at different speeds. This can lead to energy conservation, reducing carbon emissions in the shipping industry (20).

Conclusion

The Global South must recognise that economic prosperity comes with greater accountability for environmental conservation. Advancing the blue economy requires a swift transition to greener practices. While binding agreements ensure policy stability, a non-binding approach can initiate cooperation, setting the stage for future commitments. This strategy can encourage broader regional participation, fostering a more sustainable and prosperous Asia.

KEY TAKEAWAYS

Although countries can work independently to develop their agendas to grow and nurture their blue economies, cooperation among like-minded countries within the region can encourage a pooling of resources to the advantage of all member countries.

To promote blue economy growth, countries need to identify priorities in their regional green development agenda, including sharing technology and innovation, emphasising conservation, leveraging indigenous knowledge, and developing technical assistance programmes and best practices.

The Global South should realise that its economic rise also increases its accountability to protect and conserve the planet.

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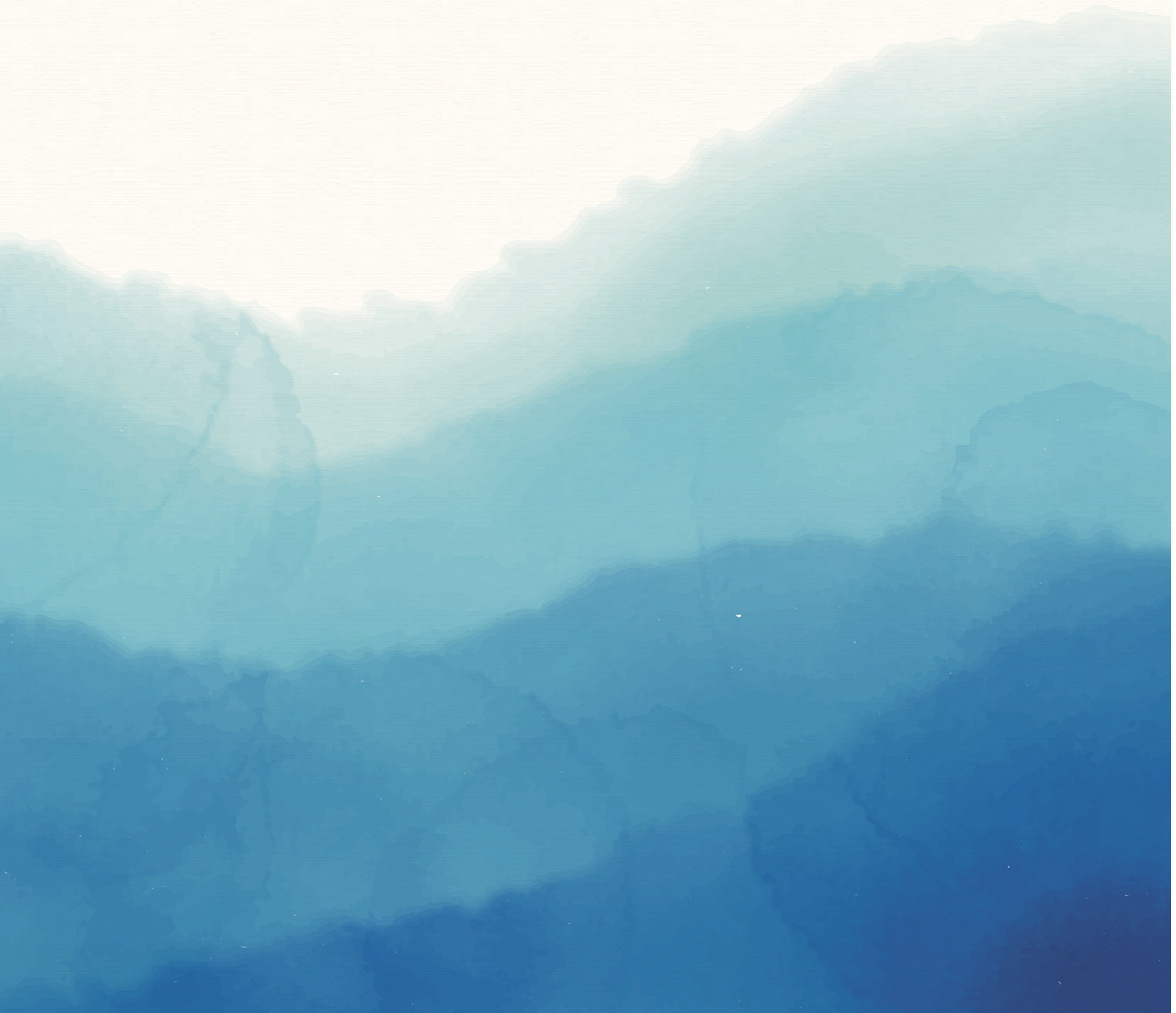
A Plea for the South Blue

Teenah Jutton



With global land resources nearing depletion, humanity must turn to the ocean's vast potential for survival. The French phrase *La mer nourricière* (the feeding ocean) has never been more relevant, underscoring the urgent need for a sustainable and resilient blue economy. This essay explores the blue economy's role in fostering prosperity and sustainability, focusing on small island developing states (SIDS) and Mauritius.

Mauritius and the Blue Economy

SIDS face increasing challenges such as coastal erosion, marine pollution, and coral bleaching, which threaten their sustainable development (1). Despite its small land area of 1,979 sq. km, Mauritius possesses a 2.3 million sq. km exclusive economic zone—the world's fifth largest—and jointly manages an additional 396,000 sq. km with the Seychelles (2). While its blue economy spans tourism, fishing, aquaculture, maritime services, and marine biotechnology, it remains evident that vast marine resources are still largely untapped, representing a missed opportunity for growth. Significant opportunities lie in hydrocarbon reserves off East Africa and Madagascar, inactive hydrothermal fields (3), polymetallic nodules (4) and mineral deposits (5).

Additionally, Mauritius faces a rising sea level of 5.6 mm annually—nearly double the global average (6). To address climate risks, Mauritius has implemented several sustainable policies related to climate change and sustainable tourism, investing 2 percent of its GDP in environmental and climate policies (7). The Climate Change Act underscores the island-nation's commitment to global climate agreements such as the United Nations (UN) Framework Convention on Climate Change, the Kyoto Protocol, the Paris Agreement, and other related instruments, aiming to reduce greenhouse gas emissions by 40 percent and generate 60 percent of energy from renewable sources by 2030. In collaboration with international institutions and experts, Mauritius has embarked on a series of coastal rehabilitation, mangrove propagation, and flood management initiatives to further support resilience-building efforts (8).

Challenges

The most daunting challenge in tapping the enormous potential of the blue economy in this part of the world lies in the appalling paucity of financial and technical/technological resources, private investments, know-how/skills, research, and other capacities.

SIDS require consistent and accessible climate finance from the international community. To facilitate this, international financial institutions and development partners are being urged to simplify and streamline access to these crucial funds (9). Deliberations at the COP29 summit in Baku, Azerbaijan, in November 2024 marked a significant step forward with the adoption of a New Collective Quantified Goal on Climate Finance (10). This commitment aims to triple financial support to developing countries, increasing from the previous target of US$100 billion annually to US$300 billion annually by 2035 (11). To ensure a more effective and equitable allocation of resources, international financial institutions should integrate the UN's Multidimensional Vulnerability Index into their decision-making processes, recognising the unique challenges faced by SIDS (12).

The Way Forward

For the blue economy to truly prosper and sustainable growth and development to be achieved, stronger and more committed international cooperation is a sine qua non. For instance, after the MV Wakashio oil spill off Mauritius in 2020, the UN (through agencies like the International Maritime Organization, the UN Office for the Coordination of Humanitarian Affairs, and the UN Development Programme) provided technical expertise and coordination to support the Mauritian government's response, including environmental impact assessments and capacity building (13).

To this end, co-financing projects through win-win partnerships with local businesses/governments by more advanced economies in the form of grants, loans, and microfinancing opportunities for small businesses and local communities must be explored.

The South often faces technological and knowledge gaps in sustainable management. The European Union (EU), with its expertise, can aid by transferring advanced technologies in offshore wind energy, aquaculture, and marine pollution management, fostering sustainable local industry growth.

Educational programmes, training, and internships can strengthen human capital, while North-South university collaborations can enhance capacity-building in marine science, policy-making, and sustainable maritime practices (14). Global visiting scholars can further support Mauritius by providing insights for informed policymaking on challenges faced by SIDS.

It is widely acknowledged that Europe has significant expertise in formulating and implementing policies for sustainable ocean governance. By offering policy support, it can help shape the development of the blue economy in the South. EU policies, such as the Common Fisheries Policy and the Marine Strategy Framework Directive, are models of sustainable ocean governance (15). While Mauritius has a strong fisheries partnership with the EU through the Sustainable Fisheries Partnership Agreement, Europe can further support southern countries by helping them design and implement policies tailored to suit local needs (16). This could include setting sustainable fishing quotas, establishing marine protected areas, or reducing coastal pollution. Furthermore, European countries can support regional cooperation initiatives that can promote cross-border collaboration on shared maritime challenges and opportunities, including the sustainable management of marine resources, maritime security, and coastal development.

Mauritius is actively working to expand and protect mangroves to combat erosion (17). Developed nations can further support developing countries and SIDS in developing climate adaptation strategies specifically designed for coastal and island communities (18). This includes investing in climate-resilient infrastructure such as flood defences, sustainable coastal tourism, and nature-based solutions.

Fostering innovation, improving governance, and sharing best practices can significantly benefit the Global South. Advanced states can support sustainable fishing, combat illegal fishing, and promote responsible aquaculture by training local fishermen and fish farmers, and establishing seafood traceability systems. The island of Rodrigues, where fishermen have been trained in sustainable octopus fishing with designated annual closure periods from August to October, is an apt example (19).

Coastal and marine tourism are key sectors for many Southern countries such as Mauritius, but they often face overexploitation. Developed states can help promote sustainable tourism models that cater to the environment and maximise local community benefits, such as creating certifications for environmentally friendly tourism operators (20).

Supporting the growth of blue economy startups and innovation hubs in the Global South through funding, networks, and mentorship can drive advancements in marine biotechnology, renewable energy, and environmental

monitoring. Launching green and blue incubator schemes will foster sustainable innovation and economic growth (21).

European countries can utilise their leadership in international organisations, such as the UN and the World Bank, to advocate for stronger international ocean governance and push for the global recognition of the blue economy as a key driver of sustainable development, in line with goal 14 of the Sustainable Development Goals (life below water). By raising awareness and advocating for policies that support the blue economy, the Indian Ocean can become an integral part of the global development agenda.

KEY TAKEAWAYS

Harnessing the blue economy for sustainability: The blue economy presents a significant opportunity for sustainable growth by promoting responsible marine resource use, protecting ecosystems, and fostering innovation to address global challenges such as food security, climate change, and poverty.

Overcoming key challenges: Realising the full potential of the blue economy requires addressing critical issues such as resource management, pollution, and climate change through careful planning, global cooperation, and a strong commitment to sustainability.

Role of developed nations in advancing the blue economy: Developed nations play a crucial role in supporting the blue economy in the Indian Ocean region by providing financial aid, facilitating technology transfer, strengthening policy frameworks, and promoting marine conservation.

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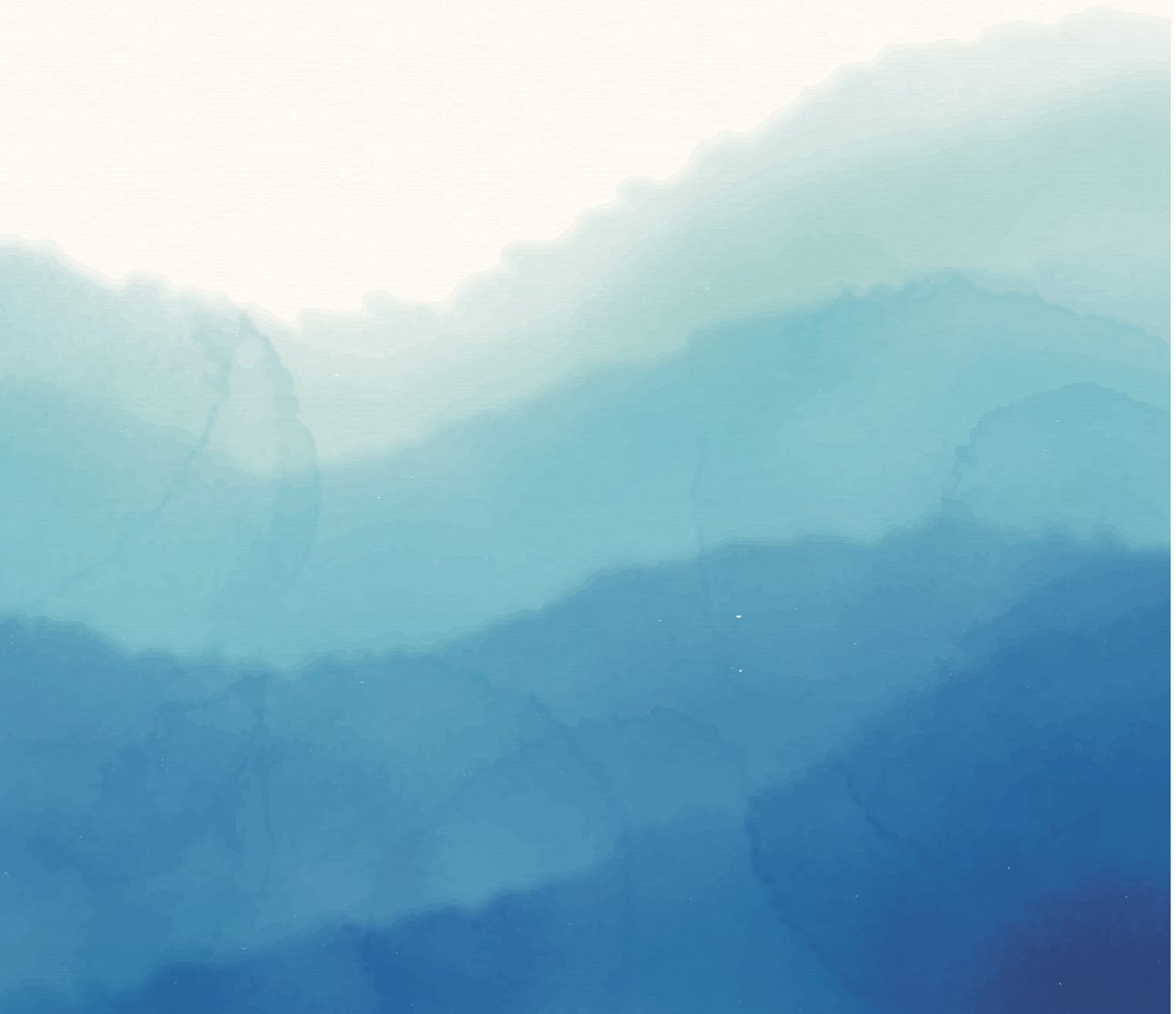
Towards a Maritime Circular Economy with an India-EU Partnership

Raimund Bleischwitz and Rüya Perincek



The world is facing a growing crisis, driven by the decline in biodiversity, escalating climate change impacts, the vulnerabilities of coastal communities, and ineffective ocean governance. These challenges demand transformative solutions, and innovation is the key to turning them into opportunities for the future. To address these pressing issues, this essay advocates for stronger international cooperation on the circular economy with a strengthened India-European Union (EU) partnership.

India and the EU: Two Giants with Resource Dependencies

India is on track to become the world's third-largest economy (1), but resource constraints hinder its remarkable growth. Excelling in digital innovation with a young, skilled workforce, India relies heavily on importing natural resources worth around US$250 billion annually, particularly fossil fuels, minerals, metals and fertilisers (2). As green technologies rise, the demand for tech metals such as copper, rare earth elements, and lithium will require massive imports.

The EU faces a similar situation. In 2022, its import bill for commodities totalled about US$1.4 trillion (3), more than double that of the US. Yet, the EU suffers from a significant material leakage, particularly in e-waste, where valuable materials are exported without being recovered. This underscores the urgent need for enhanced materials circularity to boost local value.

Current recycling efforts fall short. Only 3 percent of light rare-earth elements and zero battery-grade lithium are sourced from recycled materials (4). Europe's overall circular material use rate has stagnated at a mere 10-11 percent (5). Steel, a critical material for both infrastructure and low-carbon technologies, is a key example and can be considered a swing industry; production either continues with high carbon costs or transforms towards a secondary steel route with up to 90 percent less carbon emissions. Yet, the EU is a net exporter of scrap steel, and India depends on scrap imports to the tune of US$5.8 billion annually (6).

These trends highlight the urgent need for systemic changes. To drive sustainability, economies must innovate and strengthen markets for secondary materials, leveraging digital tools and cutting red tape to support innovative companies recovering these precious materials.

The Case for Circular Economies

The model of a circular economy (7) is driving systemic changes through better product design and novel services that target markets for secondary materials. A circular economy adds value to industries and societies. It creates jobs and offers a self-sustaining innovation trajectory, driven by the Internet of Things, artificial intelligence, machine learning, and other technologies.

India has embarked on its journey towards a circular economy. The Circular Economy Cell under NITI Aayog facilitates further initiatives, including the Swachh Bharat Mission, Jal Jeevan Mission, and dedicated efforts towards a vehicle scrapping policy (8). The EU has been on this journey for over 10 years now, with a fully-fledged new circular economy action plan adopted in 2020, and a range of policies, all underpinned by sound monitoring of circularity (9). For both, however, there is a long way ahead.

The EU and India at a Crossroads

The EU has unveiled its Clean Industrial Deal (10), with the circular economy taking centre stage. In its pursuit to reduce supply dependencies, boost competitiveness, and accelerate decarbonisation, the EU's commitment to circularity is no longer optional but essential. It signals an ambitious leap towards stronger and cleaner growth, and enhanced economic resilience.

As the EU seeks to establish clean trade and investment partnerships (11) with various countries, these agreements could emphasise resource and recycling collaboration. Reinforcing its existing raw material partnerships could come with specific cooperation on circularity. This perspective could become a pillar in the emerging India-Middle East-Europe Corridor (IMEC) (12), which could be designed as a seamless two-directional stream for secondary materials.

To address these issues, the EU should leverage its Global Gateway strategy (13) to build a partnership with India, focusing on collaboration in recycling infrastructure, from collection and sorting to processing. While this approach has a bottom-up approach, scaling it within an EU-India framework will optimise the allocation of valuable materials, set standards, and drive down circular economy system costs. With competition for secondary materials intensifying, especially in the steel sector (14), emerging powers like Saudi Arabia (15) are establishing partnerships with countries such as Zambia, Rwanda, and Paraguay to lead in metal and mineral waste management.

There is a clear case for policy learning and a robust EU-India partnership. In a global context (16), joint efforts between India and the EU could establish polycentric hubs, positioning both to lead in innovation. This collaborative approach will break free from zero-sum thinking, offering shared global benefits and multiplying opportunities across the board.

International Interdependencies: The Case of Ship Recycling

Numerous accidents occurring in shipbreaking (17) in South Asia illustrate the prolonged practice of shifting responsibilities away from the EU; just 1 percent of ships (18) under EU ownership are estimated to be recycled domestically. India is well-positioned to pave the way by implementing the Hong Kong Convention on Ship Recycling (19), to become the foremost recycler. The challenge is driving innovation in automation, robotics, and advanced material processing to handle the 100-150 mn tonnes of high-quality steel expected to come from dismantling tankers and vessels over the next 10 years (20). The shipping industry is at a turning point: pledges for climate neutrality will need to be supported by new production based on decarbonised secondary steel, which lowers the carbon footprint by about 80 percent if the electricity needed for this route is green (21). The EU Ship Recycling Regulation directive, which is being revised, could transform international standards and facilitate innovation alliances. Aligning the Alang shipbreaking yard in India with European coastal actors could be at the core of such an alliance, involving the coordination of policies, the development of joint infrastructure projects, and using the certification, compliance and enforcement of standards to drive sustainable shipping and decarbonisation of steel.

Towards a Maritime Circular Economy: Shipping, Energy, Materials, and More

With over 1,200 ports and 68,000 km of coastlines (22), three times longer than the US and nearly twice that of Russia, the EU has a unique opportunity to transform its ports into innovation hubs for material circularity. A maritime circular economy, driven by international trade and repurposing offshore energy infrastructures, could become a strategic project for both India and the EU. This could lead to the creation of low-carbon clusters in ports and coastal regions. Recapturing and reusing critical materials from energy technologies such as wind energy turbines, which contain up to 300 kg of rare earth elements (23) along with e-waste, could become another business cluster, feeding into the processing capabilities for digital technologies.

A circular and blue bioeconomy is also emerging, with coastal ecosystems (24) offering immense potential. Integrated multi-trophic aquaculture, novel marine

foods, and blue carbon (25) projects are a few promising opportunities towards climate neutrality, biodiversity improvements, and food security. Tackling marine plastic litter (26) has already been identified as a shared EU-India objective and could lead to novel innovation pathways.

Building Strategic Partnerships

Transatlantic relations are increasingly fragile. China pursues its style of multipolarity via the Belt and Road Initiative, which may leave India as a bystander rather than a major player. A strong green and blue India-EU partnership that elevates partnerships in energy and raw materials will be crucial in enabling resilient innovation alliances and ensuring that India and Europe not only lead in sustainability but also connect via the IMEC while securing access to essential resources in an interconnected world. Together, India and Europe could become a hub for knowledge, technology and innovation, connecting clusters of industries, ports, and people.

KEY TAKEAWAYS

The transition to a circular economy offers an opportunity for both India and the EU to reduce dependency on external resources and drive innovation in green technologies. Coastal areas will be key in connecting material flows and leveraging a sustainable blue circular economy.

There is a strong case for deeper cooperation between India and the EU, particularly in areas such as recycling infrastructure and resource management. The EU's Global Gateway strategy offers a unique opportunity to support India's circular economy initiatives by advancing material recovery and recycling innovations.

A robust EU-India partnership focused on green and blue economy initiatives, including sustainable shipping, recycling, and the blue bioeconomy, will enable the two sides to lead in sustainability and position them as global leaders in innovation and resource management.

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**Disclaimer: The views expressed do not represent the official position of the European Commission.*

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Blue Triple-Use: Unlocking Portugal–India Geoeconomic Synergies

Ruben Eiras

A new investment trend is emerging in the blue economy known as 'triple-use', where technologies serve civilian, defence, and environmental purposes. This approach is gaining momentum in Europe, driven by geopolitical shifts such as the Russian aggression in Ukraine and the Transatlantic disengagement under the Trump administration in the US. These developments have compelled the European Union (EU) to increase defence spending without compromising the welfare state.

To strike a balance, defence investments must stimulate new civilian industries that generate tax revenue to sustain social policies. Simultaneously, these technologies must protect Europe's blue assets, addressing security and sustainability. Why is this critical? Europe is a densely populated subcontinent bordered by the Atlantic, Arctic, and Mediterranean Seas (1). The seas are vital for expanding sustainable food and energy production through offshore aquaculture and floating wind farms, but are also vulnerable to military threats. Moreover, the EU is a maritime-dependent economy, with 74 percent of its goods trade transported by sea (2).

In this context, the 'big blue' is no longer just an ecological or economic frontier—it has become a strategic domain requiring coordinated policy and investment. The ocean now underpins multiple pillars of European security:

- Food security, as the primary source of low-cost, low-carbon protein through onshore and offshore sustainable aquaculture (3)
- Energy security, with vast potential for renewable energy generation via floating offshore wind and wave power (4)
- Trade security, as the main global transport channel. The majority of the EU's goods trade moves by sea (5)
- Climate security, through its role as the planet's largest carbon sink (6)
- Infrastructure security, by hosting critical underwater cables that carry information, energy, and communications (7)
- Mineral security, as the main source of rare earths and minerals essential for the digital and green transitions (8)

This is where the blue triple-use concept emerges. It is a new investment approach supporting startups and companies that develop dual-use digital technologies (civil and defence) with a third layer—sustainability. Unlike traditional dual-use models, this approach ensures that ocean industries also protect natural marine assets. The synergy created by the blue triple-use model (9) is key to building a strong pipeline of startups and investment-ready companies with solutions that go beyond dual-use, and are aligned with the vision of Mario Draghi's *Future of Competitiveness* report for the European Commission (10), as follows:

- Civil: Development of new hardware and software technologies that enhance the digitalisation of the ocean, making businesses across the 10 value chains of the blue economy more accessible, efficient, and innovative
- Defence: Advanced technologies that strengthen the protection of maritime territories and assets, making defence capabilities more effective and widely accessible
- Sustainability: Technologies that, through ocean digitisation and improved defence of blue assets, also contribute to environmental goals, such as decarbonisation and operational efficiency, aligned with the EU taxonomy for sustainable activities (11).

The triple-use approach offers significant growth potential by meeting the demand for sustainable, efficient ocean solutions. Adopting digital technologies further boosts profitability and ESG (environmental, social, and governance) performance.

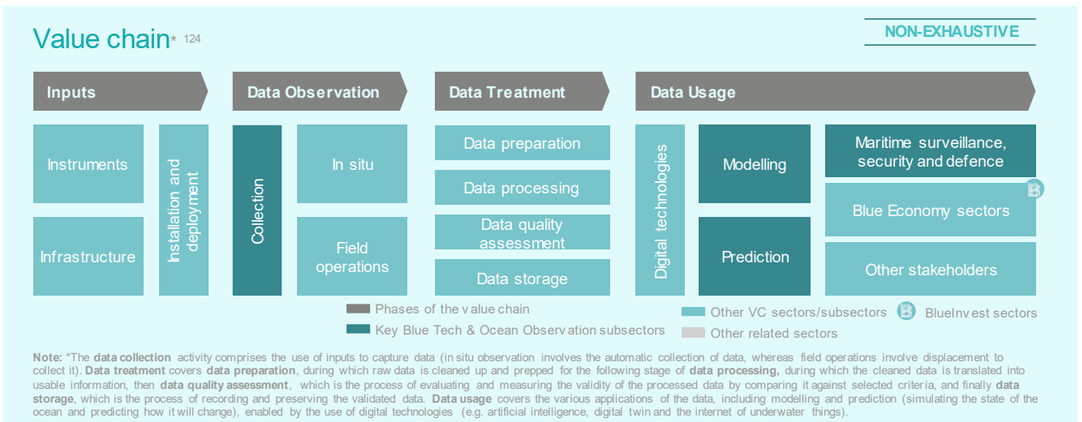
Fórum Oceano is the managing entity of Portugal's Blue Economy Cluster, officially recognised by the Ministry of Economy and the Sea (12). As a non-profit organisation, its mission is to foster the sustainable growth of Portugal's maritime economy by promoting innovation, entrepreneurship, and collaboration across the sector (13). It leads various initiatives and projects aimed at boosting the competitiveness of maritime-related businesses and institutions (14). Its key activities include supporting research and development in emerging technologies, facilitating access to financing and investment, and promoting internationalisation (15). With a network of over 160 members, including companies, business associations, universities, research centres, and local authorities, Fórum Oceano plays a central role in advancing Portugal's leadership in the blue economy (16).

To streamline its efforts, Fórum Oceano is structured around 10 strategic value chains: fisheries & seafood; aquaculture; blue biotechnology; water management; ports and shipping; environmental protection and regeneration; bluetech and ocean observation; blue renewables; shipbuilding and refit; and blue tourism (17).

Among these, bluetech and ocean observation hold significant potential for generating quick wins. By applying advanced digital technologies, such as robotics, satellite-maritime systems, artificial intelligence (AI), and blockchain, across different maritime sectors, this value chain supports a dual-use approach (civil and defence). When sustainability is integrated, these innovations advance towards triple-use solutions (see Figure 1).

The bluetech and ocean observation sector transforms ocean data into actionable insights for services, science, and policy (18). It involves data collection, modelling, and forecasting, supported by ocean sensing and imaging tools, integrated systems, maritime robots, sensor-equipped submarine telecommunication and energy cables, fixed and mobile platforms, and research vessels, all powered by advanced blue digital technologies (19). In addition to monitoring ocean conditions, tracking human activity at sea is vital. Maritime surveillance, security and defence support EU and national efforts to safeguard maritime domains (20). While defence is primarily led by naval forces, maritime safety and surveillance focus on navigation, the operational and technological integrity of vessels, and the rescue of people in distress (21).

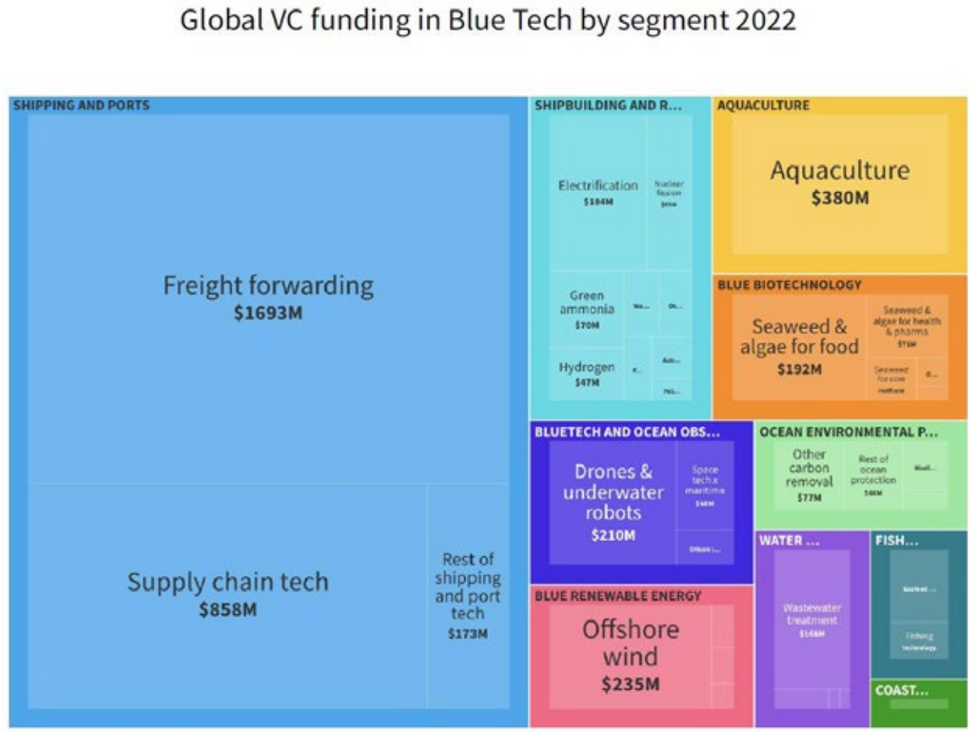
Figure 1: Bluetech and Ocean Observation Value Chain



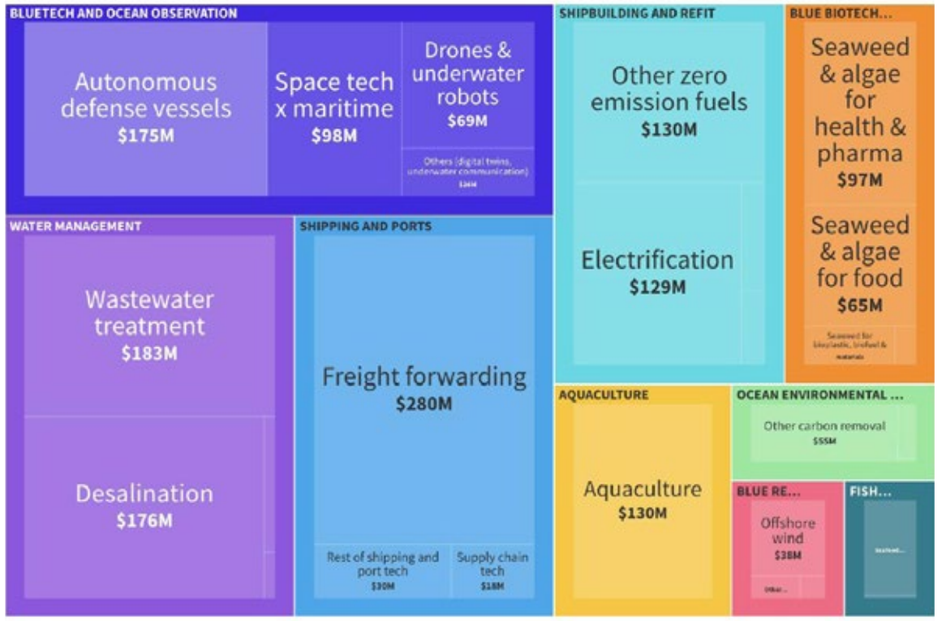
Source: *Blue Invest Report 2023 (22).*

Bluetech and ocean observation are the ultimate playground for triple-use investments in the blue economy. The digital transformation of this sector—and the vast data it generates—enhances the understanding of ocean processes and the human activities that affect them. This knowledge drives targeted action to protect marine ecosystems, predict climate change impacts, and build resilience. At the same time, maritime defence, through innovation and advanced surveillance technologies, plays a critical role in enforcing conservation measures, leveraging satellites, drones, and AI to support environmental preservation and decarbonisation goals (23). This is where the triple-use model comes to life in the blue economy. Data from the Hub Azul Dealroom platform, managed by Fórum Oceano, shows that between 2022 and 2024, the bluetech and ocean observation sector emerged as the top choice for venture capital investment (see Figure 2).

Figure 2: Hub Azul Dealroom Global VC Bluetech VC Funding, 2022 vs 2024



Global VC funding in Blue Tech by segment 2024



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Investing in Triple-Use in the Blue Economy

Digital technologies in the blue economy can adopt what may be termed a 'blue-as-a-service' model—an ocean-focused evolution of the software-as-a-service approach. This model enables efficient, scalable solutions across maritime value chains, enhancing energy and operational efficiency, expanding data collection and processing, and accelerating insight generation. Key service offerings may include: digital twin modelling, operations management software (for autonomy, automation, energy and operational efficiency), predictive risk analytics software, sensing and monitoring technologies, high-speed data-to-information processing tools, market platforms for ocean services and products, big data services for maritime intelligence, and asset traceability systems.

Now is the moment to invest in the blue economy by promoting the adoption of key technological families across all value chains through a triple-use perspective:

- **Technology Family 1: Smart sensors for ocean monitoring and ship reconnaissance**

Real-time sensors—often embedded in submarine cables—monitor conditions like salinity and temperature, offering vital insights into underwater ecosystems and vessel environments. These technologies support better decision-making, enhance maritime safety, and deepen our understanding of the ocean (25).

- **Technology Family 2: Unmanned systems for data collection and surveillance**

Automated robots—both aerial and aquatic—collect real-time ocean data for inspections and exploration. These systems improve the understanding of ocean-climate interactions, support blue economy sectors, and enhance monitoring and surveillance, including rescue operations and detection of illegal activities (26).

- **Technology Family 3: Fixed and floating platforms for ocean observation**

Floats and platforms monitor and transmit real-time ocean data, supporting offshore infrastructure such as wind turbines. By measuring temperature and salinity across global oceans, they play a vital role in tracking and responding to climate change (27).

- **Technology Family 4: Digital twins**

Digital twins of the ocean, built from real-time and historical data, help monitor and predict interactions between natural and human activities. They enhance understanding and support more informed, forward-looking decision-making (28).

- **Technology Family 5: Digital technologies for ocean observation**

Technologies like high-performance computing, AI, big data, and the underwater Internet of Things enhance connectivity, data modelling, and prediction. Their application accelerates the understanding of the ocean, supports reliable decision-making, and strengthens maritime safety and environmental protection (29).

Portugal presents a strong business opportunity for developing a robotics-digital technology industry focused on the sea. This is supported by a growing national knowledge base, driven in part by the Portuguese Navy's continued

support in its Hydrographic Institute (in 2026, it will have a hub for startups, and already hosts the big data platform, Hidrographic+) (30) and the annual REPMUS (Robotic Experimentation and Prototyping with Maritime Uncrewed Systems) exercise (31). Organised in partnership with NATO and the University of Porto, REPMUS is one of the world's largest testing events for uncrewed maritime systems, bringing together military forces, universities, and tech companies to advance interoperability and innovation (32). Fórum Oceano, in collaboration with the Portuguese Navy, is fostering synergies between REPMUS and national innovation platforms such as Hub Azul Portugal and the Portugal Blue Digital Hub.

Conclusion: The Geoeconomic Case for Portugal-India Cooperation in a Triple-Use Blue Economy

Portugal and India share a common ocean challenge: both have vast maritime zones that are difficult to monitor and protect using conventional technologies. India's exclusive economic zone (EEZ) spans 2.3 million sq. km (33), while Portugal's 1.7 million sq. km EEZ represents 11 percent of the EU's total EEZ (34).

By combining their scientific, technological, and business capabilities in triple-use technologies, the two nations can strengthen sovereignty over a strategic natural asset: the ocean. This collaboration is crucial for ensuring geoeconomic resilience in the current turbulent geopolitical climate. Applying digital technologies across blue economy value chains offers triple benefits:

- Economic: Profitable services built on data-driven insights for blue sector operations.
- Environmental: Measurable sustainability outcomes aligned with ESG and EU taxonomy goals.
- Security: Enhanced surveillance and defence of maritime assets.

Investing in new technologies that ensure efficiency, protection, and sustainability in the blue economy is strategic and essential. Portugal and India are well-positioned to become global testbeds for these triple-use blue technologies, proving that economic growth and ecological responsibility can go hand in hand.

In an era where the US is stepping back from its role as a free trade anchor, India can step forward, joining the EU in shaping a coalition of democratic economic blocs where financial growth means a welfare state that ensures food and affordable housing for all.

India and Portugal—both historic maritime nations—now have an opportunity to forge a powerful partnership in the blue economy. As a key maritime EU country, Portugal can be a strategic entry point for India to expand its bluetech and ocean observation value chain. Together, the two countries can co-develop triple-use technologies to protect maritime assets, foster new industries, and safeguard ocean health.

A joint science and technology agenda supported by both governments could lay the groundwork for applied research in this field. This could be followed by an annual India–Portugal Blue Investment Forum to promote commercial opportunities arising from innovation. Fórum Oceano can catalyse this cooperation, combining the strengths of both nations to build a blue industry that balances economic growth with ecological responsibility.

KEY TAKEAWAYS

India and Portugal face the strategic difficulty of monitoring vast maritime zones beyond the reach of conventional technologies.

Investments in maritime defence should foster civilian industries that generate tax revenue to support social welfare, while simultaneously protecting marine assets for both security and sustainability.

India and Portugal are well-positioned to become global testbeds for triple-use blue technologies—advancing defence, civilian innovation, and ocean sustainability without compromising ecological health.

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Section III

Green and Blue: Sustainability, Technology, and Innovation

Emerging Challenges in Achieving Environmental Sustainability in Shipping: Focus on India

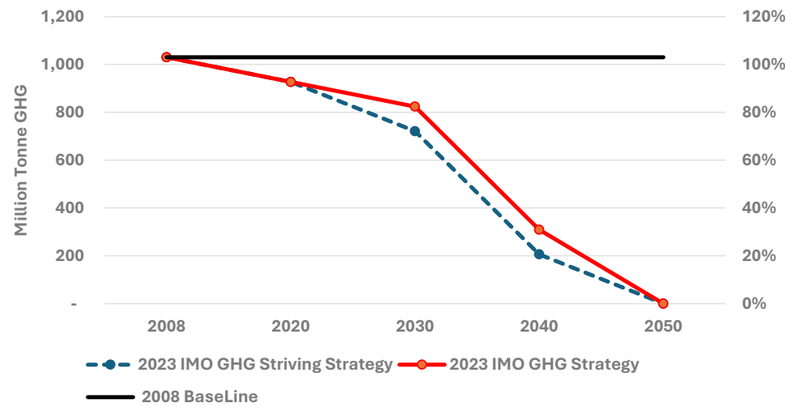
Ahmed Hussein Selim

The maritime sector is a fundamental pillar of international trade, with more than 85 percent of global trade conducted via oceans and seas, accounting for 2.89 percent of global emissions (1). The International Maritime Organization (IMO) aims to achieve zero emissions by 2050, which will present challenges for developing countries, including India. One key factor in addressing these challenges is the role of the Suez Canal route, which reduces distance, fuel consumption, and emissions between Europe and Asia compared to the longer alternative around the Cape of Good Hope.

The IMO's Ambitious Targets

The shipping sector is the most efficient in terms of emissions per unit, responsible for more than 85 percent of global trade, while accounting for only 2.89 percent of global emissions (2). Despite this, the IMO launched its initial strategy in 2018, aiming to reduce shipping emissions by 50 percent by 2050, relative to 2008 levels (3). In July 2023, the IMO adopted the strategy with ambitious targets to decrease emissions by 20 percent to 30 percent by 2030 and by 70 percent to 80 percent by 2040, and to achieve net-zero greenhouse gas (GHG) emissions by 2050 (see Figure 1).

Figure 1: GHG Emissions from the World Shipping Fleet and IMO's Targets



Source: *International Council on Clean Transportation (4).*

The IMO launched the short-term policies (STPs) in 2011 and enforced them on 1 January 2013. First, the Energy Efficiency Design Index was applied to

newly built ships in three phases, with each phase targeting a minimum 10 percent increase in energy efficiency depending on the type and size of the ship (5). Second, the Ship Energy Efficiency Management Plan was introduced for all vessels to promote continuous improvements in operational efficiency. Third, the IMO Data Collection System was introduced in 2019, requiring all ships to collect and report fuel consumption data annually. Fourth, in 2021, the Energy Efficiency Existing Ship Index was applied to existing ships with measures almost identical to those of the Energy Efficiency Design Index, along with the Carbon Intensity Indicator, which applies to all ships by measuring the amount of CO_2 emissions per tonne of cargo transported over a given distance (6).

The STP has played a significant role in pushing the shipping sector to adopt new technologies. However, this policy has negatively impacted shipping speeds (for instance, decreasing the speed of container ships by 28 percent) (7, 8).

The mid- and long-term policies will focus on two elements: a technical element, which is a goal-based marine fuel standard to reduce emission intensity, and an economic element, which refers to the levy on GHG emissions to reduce the price gap between traditional fossil fuels and alternative fuels (9). The carbon tax is expected to increase shipping costs by an average of US$9.9 per tonne.

India's Growing Influence

India, now the world’s most populous country and the fifth-largest economy, is projected to become the third-largest global economy by 2030 (10). It remains a crucial hub for marine operations and crewing. India is the world’s second-largest seaborne importer, accounting for 6.6 percent of global imports (11). However, India ranks tenth in exports, contributing 1.8 percent of global seaborne trade (12).

Emissions-reduction policies in the shipping sector will impact India’s trade by an average of US$10.5 billion annually, requiring a strategic plan to mitigate these effects. This includes modernising Indian ports to supply alternative fuels, upgrading the Indian fleet to use cleaner fuels, and adopting technologies to improve fuel efficiency and reduce emissions. Additionally, Indian shipping operations will face higher costs due to the carbon tax.

- **Strategic location and connectivity**

India is classified as a peninsula, which gives it a strategic advantage in the maritime sector. Additionally, its location on the main trade route between the North and South enhances its access to European, African, and American markets, offering the country the fastest route for importing and exporting goods via shipping, particularly through the Suez Canal route, which reduces the distance for Indian trade with Europe and the Americas by approximately between 20 percent to 60 percent compared to the Cape of Good Hope route, depending on the origin and destination ports (13).

The Suez Canal route, which represents 12 percent of global trade, contributed to saving more than 16.9 million tonnes of fuel in 2023, equivalent to a reduction of 55.4 million tonnes of carbon emissions (14). However, the disruptions in the Red Sea in 2024, which forced vessels to take the Cape of Good Hope route, resulted in an increase in global shipping emissions by more than 32 million tonnes, delays in goods delivery, and higher shipping costs (15). These disruptions severely impacted India's trade, particularly with Europe, causing delays of up to three weeks, a dramatic surge in freight rates, and increased costs for several goods, especially low-value exports such as agriculture and textiles (16, 17).

Trade through the Suez Canal route is expected to increase in the coming decades as trade patterns shift. Therefore, the Suez Canal Authority has been continuously developing the navigation channel and updating the marine units, completing two major projects over the past decade that have doubled the canal's capacity (18).

Regional and international cooperation with countries along the Suez Canal route is essential for enhancing India's future trade prospects, enabling more efficient access to key international markets, and fostering long-term economic growth.

Conclusion

The IMO's short-term policies have slowed the growth of emissions in the global shipping sector, but they are insufficient to achieve net-zero emissions by 2050. The upcoming mid- to long-term policies are expected to be more stringent, adding additional cost pressures on the shipping industry, particularly in developing countries like India. India's economy and maritime trade are on the rise, driven by low production costs and its strategic location, which

links it to key international shipping routes. The Suez Canal route is vital for transporting Indian goods to European and American markets. However, continuous strategic support is needed to ensure the route's long-term sustainability and stability. Indian authorities should focus on developing key hub ports, building a national fleet that meets environmental standards, facilitating the transfer of shipbuilding technologies, and attracting investment, particularly in the western part of India.

KEY TAKEAWAYS

The IMO's emissions-reduction policies will impose additional cost pressures on India's shipping industry, necessitating strategic adaptation through fleet upgrades and port modernisation.

India's strategic location, low production costs, and growing sectors like electronics and textiles provide significant opportunities for trade growth, despite the environmental challenges.

The Suez Canal route is vital for India's trade and environmental concerns, providing a key passage to European and American markets. The sustainability of this route requires enhanced regional and international cooperation.

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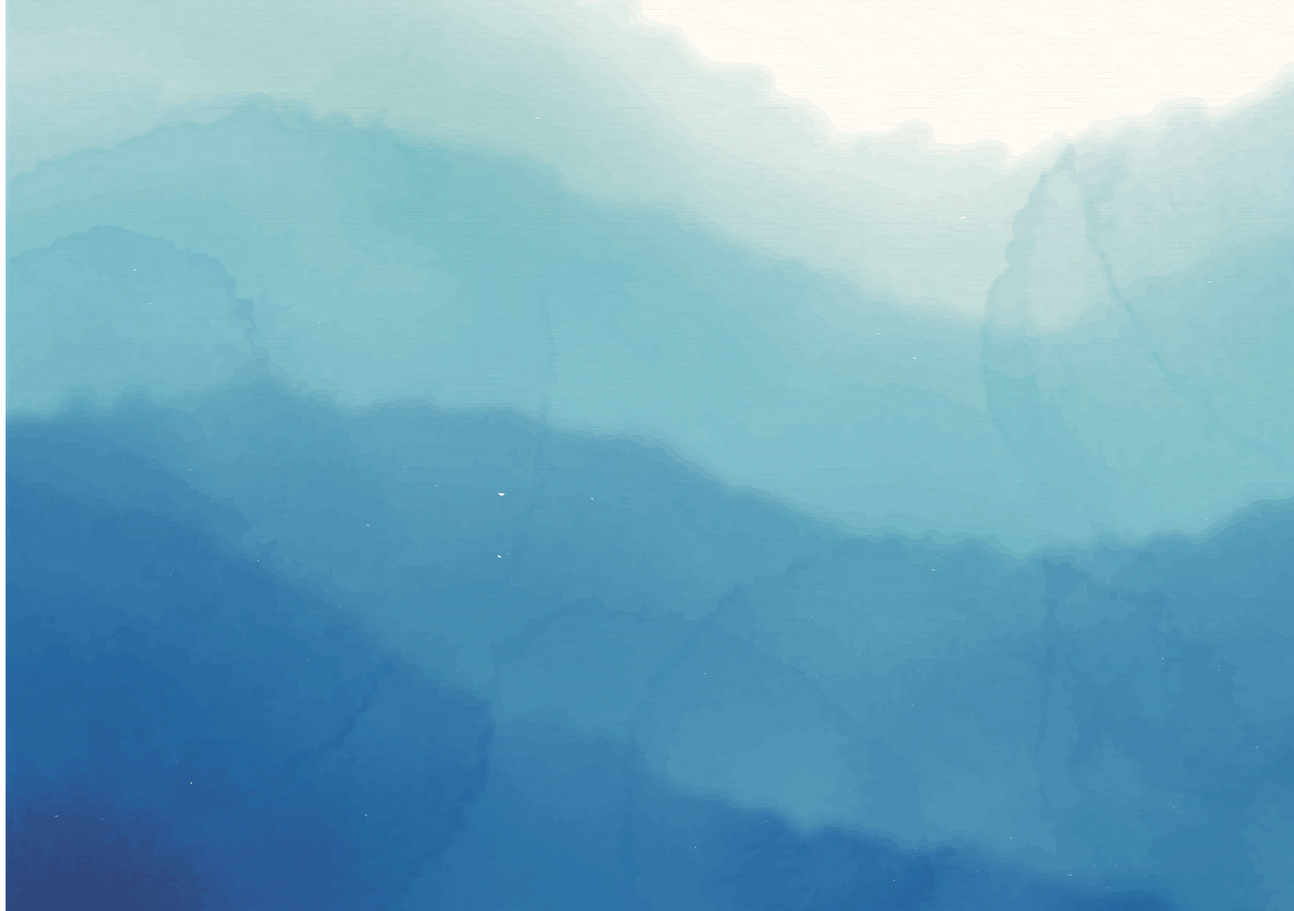
Towards Sustainable Shipping: Navigating the Future

Nancy Karigithu



Shipping, the lifeline of global trade, is on the cusp of a major transformation. While historically lauded as the most efficient and cost-effective method of moving goods across vast distances, its environmental footprint is increasingly under scrutiny and pressure to contribute to saving the planet (1). The imperative to decarbonise operations, coupled with broader sustainability concerns such as biodiversity decline, the well-being of coastal communities, and the need for more robust ocean governance, necessitate an urgent paradigm shift. This essay explores how the intersection of sustainability, technology and innovation, particularly in the context of 'green' (environmental) and 'blue' (ocean-centric) initiatives, will redefine the future of shipping.

Navigating the Challenges

The urgency to address carbon emissions in shipping stems from the industry's significant contribution to greenhouse gases. Traditional heavy fuel oil, the industry's mainstay, releases substantial amounts of sulfur oxides, nitrogen oxides, and particulate matter, impacting both air quality and climate change (2). The International Maritime Organisation's (IMO) ambitious targets for reducing greenhouse gas emissions, including an ambitious net-zero reduction by 2050 compared to 2018 levels, demand radical changes within a tight deadline, necessitating a departure from fossil fuels and adopting cleaner alternatives (3).

Innovation has assumed a role as the cornerstone of this transition. While liquefied natural gas has emerged as a transitional fuel, offering lower emissions compared to heavy fuel oil, its long-term viability comes to sharp focus due to methane slip (the unburned methane, a potent greenhouse gas, that escapes into the atmosphere during the combustion process in engines that use natural gas as fuel) and its continued reliance on fossil resources (4). The search for truly sustainable fuels is thus driving research into alternatives like ammonia, methanol, and hydrogen (5). These fuels, produced from renewable energy sources, hold the promise of near-zero emissions (6). Significant challenges, however, still remain regarding the production, transportation, storage, and distribution of these new oils as well as the necessary infrastructure (7).

Beyond alternative fuels, technological advancements have also emerged as crucial pillars for enhancing energy efficiency. Hull design optimisation utilising computational fluid dynamics (a computer-based tool to simulate the behaviour of liquids and gases) to minimise drag is becoming increasingly sophisticated (8). Air lubrication systems, which create a layer of air bubbles beneath the hull, reduce friction and fuel consumption (9). Rotor and rigid sails, harnessing wind power, offer supplementary propulsion, reducing the reliance on the engine (10). These technologies, combined with improved route planning and weather optimisation, contribute to significant fuel savings and emission reductions (11).

The 'green' agenda, however, extends beyond decarbonisation. The 'blue' dimension of sustainability highlights the need to protect the marine environment and ensure the well-being of coastal communities by integrating sustainability principles and the socioeconomic activities of ocean communities. Shipping activities can disrupt marine ecosystems through noise pollution, ballast water discharge, and the risk of oil spills (12). Ballast water, transported between ports, can introduce invasive species, threatening native biodiversity (13). Noise from ship propellers and engines can interfere with marine mammal communication and navigation (14).

Steering Toward a Blue Sustainable Future

Addressing these challenges requires a holistic approach. Ballast water treatment systems, utilising filtration and UV radiation, are becoming mandatory to prevent the spread of invasive species (15). Stricter regulations on noise emissions and developing quieter propulsion systems are crucial for mitigating noise pollution (16). Emergency response systems and improved navigational technologies are vital for minimising the risk of oil spills and other accidents (17).

Furthermore, the well-being of coastal communities, often reliant on fishing and tourism, is inextricably linked to the health of the marine environment (18). Having had historical reliance on the sea for sustenance, transport and trade, the coastal ecosystems are often woven into the fabric of their existence and integral to their economy, culture, and livelihood. Sustainable shipping practices, including responsible waste management and reducing air and water pollution, are essential for preserving these livelihoods. Developing ecotourism initiatives and promoting responsible interaction with marine ecosystems can contribute to conservation and economic development (19).

The transformative power of technology extends beyond environmental considerations. The "digitalisation" of shipping, driven by artificial intelligence (AI), the Internet of Things (IoT), and robotics, is revolutionising supply chains and business operations. AI-powered algorithms can optimise vessel routing, predict maintenance needs, and improve cargo handling efficiency (20). IoT sensors, deployed throughout the supply chain, provide real-time data on cargo location, temperature, and condition, enhancing transparency and traceability (21).

Robotics is transforming port operations, automating cargo handling, and reducing turnaround times (22). While still in their nascent stages, autonomous ships hold the potential to optimise operations further and reduce human error (23). These technologies enhance efficiency, improve safety, and reduce risks for seafarers and port workers (24).

The impact of these technological advancements on employment and livelihood dynamics is multifaceted. While automation may lead to job displacement in certain sectors, it also creates new opportunities in areas like data analysis, software development, and robotics maintenance (25). The shipping industry must invest in training and education programmes to equip workers with the skills needed to thrive in the digital age (26).

On another note, the rise of digital technologies is reshaping governance paradigms in the maritime sector. Blockchain technology, for example, can enhance transparency and traceability in supply chains, combating illegal fishing and promoting responsible sourcing (27). Digital platforms can facilitate stakeholder collaboration, enabling more effective monitoring and enforcement of regulations. Data analytics can provide valuable insights for policymakers, informing evidence-based decision-making. The rapid pace of technological change, however, also presents challenges. Cybersecurity risks are a growing concern, as the increasing interconnectedness of systems makes them vulnerable to cyberattacks (28). The need for robust cybersecurity measures and international cooperation to address these threats is paramount. The ethical implications of AI and autonomous systems also require careful consideration to ensure these technologies are used responsibly and equitably (29).

However, it is important to note that while green fuels and technology are central to the transition, success also hinges on the interplay between governance frameworks and market incentives through creating a level playing field and ensuring that all industry players adhere to the new environmental standards. Governance frameworks, particularly through international bodies like the IMO, help by establishing regulations and standards for emissions reduction, fuel efficiency, and technological adoption. This provides a baseline for sustainable practices while guiding governments in setting policy directions and the necessary legal frameworks to guide the industry towards sustainability goals, including issues related to carbon pricing, fuel regulations, and investment in green infrastructure.

Conclusion

The future of maritime shipping hinges on the successful integration of sustainability, technology, and innovation. The ‘green’ agenda, focused on decarbonisation and environmental protection, must be pursued alongside the ‘blue’ agenda, emphasising the health of the ocean and the well-being of coastal communities. While technological advancements, from alternative fuels to AI-powered supply chains, are driving this transformation, it is crucial to ensure that these advancements are accompanied by robust governance frameworks, ethical considerations, and investments in human capital.

The shipping industry must embrace a holistic approach, recognising the interconnectedness of environmental, economic, and social factors. By fostering collaboration between governments, industry stakeholders, and research institutions, and by prioritising innovation and sustainability, the maritime sector can navigate the challenges ahead and contribute to a more sustainable and prosperous future for all. The transition towards a ‘green and blue’ shipping industry is not merely an environmental imperative; it is an opportunity to build a more resilient, efficient, and equitable global trade system.

KEY TAKEAWAYS

Shipping is under increasing pressure to decarbonise and become more sustainable with increasing pressure for a ‘paradigm shift’ towards more environmentally friendly practices.

While technology and innovation have been identified as crucial for the industry's transition to sustainability, finding cleaner alternatives to traditional fuels is essential.

The IMO’s ambitious targets for reducing greenhouse gas emissions with a goal of net-zero emissions by 2050 (compared to 2018 levels) have emerged as the single most important driving force behind the industry's push for change, which highlights the regulatory pressure and a need for significant, rapid changes.

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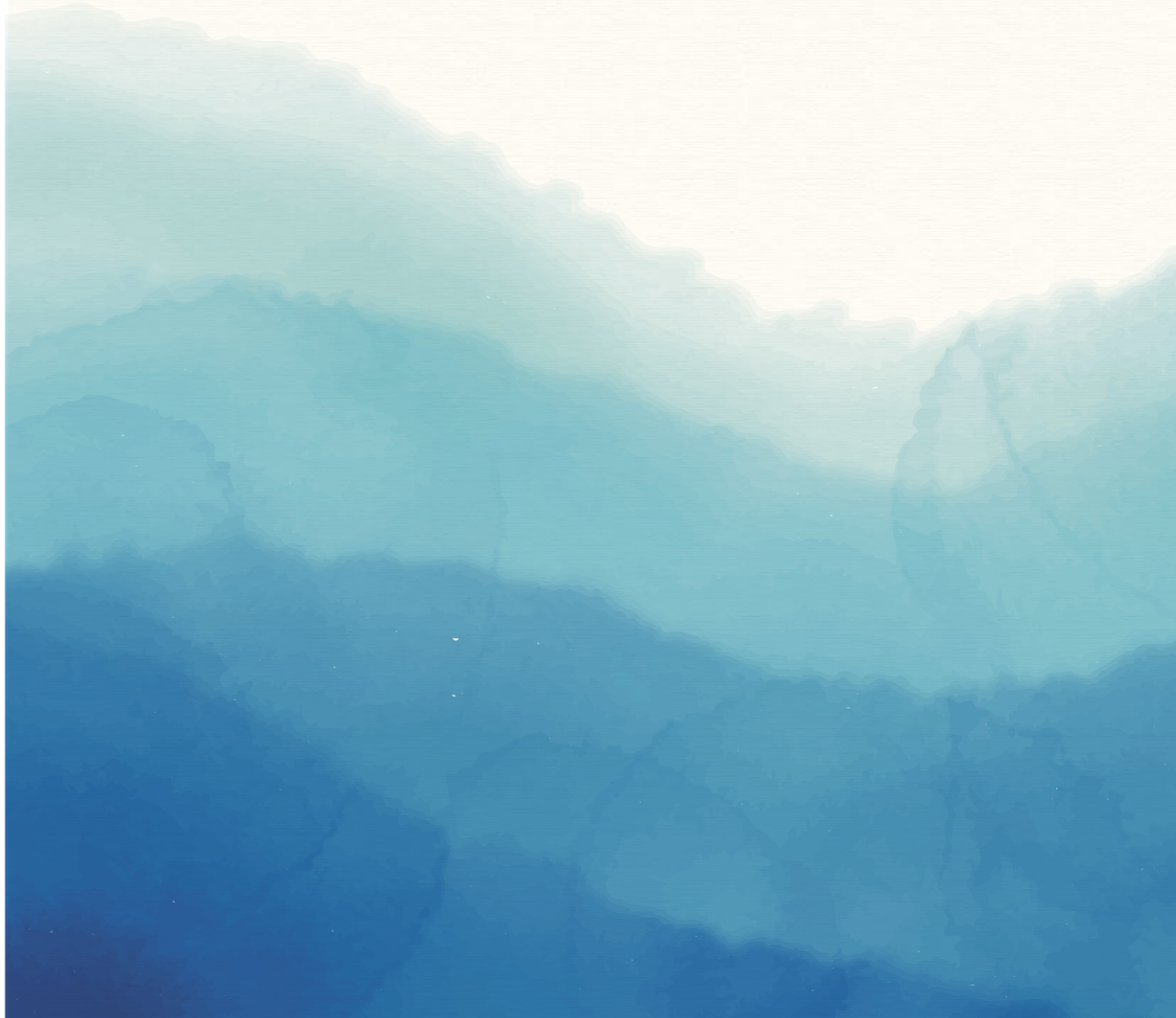
Challenges and Opportunities for Sustainable Development in the Marine Transport Sector

Linda Etta



For ages, the shipping industry has been the lifeblood of the global economy (1). Without shipping (both inland and maritime), intercontinental trade, commerce, services, and logistics would either be expensive or virtually impossible (2). Between 1990 and 2023, seaborne trade doubled to 12 billion tonnes (3). Today, the shipping industry accounts for approximately 90 percent of global trade transportation (4). Shipping fleets handle over 80 percent of global merchandise trade by volume and more than 70 percent by value (5). This has added about US$4.5 trillion to the global GDP annually (6). Most importantly, emerging coastal/shipping nations in the Global South have reaped the lion's share of these benefits (7). In 2021, emerging countries accounted for 55 percent of loaded seaborne goods and discharged 61 percent of the world's seaborne trade (8). The shipping industry accounts for about 20 percent to 40 percent of the national GDP in maritime states such as Singapore, Greece, and Panama (9). Additionally, Asia's marine shipping countries and ports are stewards in marine freight, accounting for 4.6 billion tonnes of loaded goods and 7.1 billion tonnes (64 percent) of all goods loaded at ports globally (10).

The Sustainability Imperative in Shipping

As seaborne trade is projected to expand by 2.4 percent and containerised trade by 2.7 percent between 2025 and 2029, emerging countries might reap more benefits (11). This is especially true with the increased focus on the blue economy (BE) transformation, which emphasises Global South stewardship in ocean development and sustainable development transformations beyond 2030 (12). The global sustainable BE transformation's benefits include the provision of about 13 million jobs directly (mostly to Global South citizens in India and Indonesia), such as seafarers, dockworkers, and port operators, and an additional 30 million jobs indirectly linked to shipping, such as logistics, port management, and supply chain services (13). Thus, over US$150 billion in wages is added annually to the global economy. Additionally, with the 50,000-plus merchant ships being registered in over 150 nations (contributing about US$380 billion in freight rates and being manned by seafarers of virtually every nationality), it presents an opportunity to enforce and operationalise marine institutional governance mechanisms (14).

Comprehensive governance mechanisms could reinforce the application of several international maritime and transport law conventions, non-mandatory rules (adopted under the auspices of the UN Commission on Trade and Development, or UNCTAD), maritime guidelines, safety standards and regulations, frameworks on responsible shipping (such as those embedded under the Rotterdam Rules, under the auspices of UN Commission on International Trade Law) and regional frameworks. Through this, sustainable marine human-environmental practices (such as the limited release of ballast) and the monitoring of illegal maritime activities (including sea piracy, illegal migration, and deep-sea fishing) could be achieved (15). A mix of these benefits is crucial for achieving key provisions and targets embedded under existing policy frameworks and agreements, such as the Convention on Biological Diversity, the United Nations Convention on the Law of the Sea, the High Seas Treaty, and the International Convention for the Prevention of Pollution from Ships (16). As countries push to ratify and implement these legal and institutional mechanisms, the prospects for promoting sustainable shipping practices are increasing (17). This could re-energise efforts to achieve UNCTAD's five pillars of sustainable ocean development (social, economic, institutional governance, environmental, and scientific/technological), and a sustainable ocean-based economy.

Challenges and Emerging Concerns

Despite the positive and promising indicators, the shipping sector is sandwiched between perpetual and emerging complex challenges. Human-environmental challenges have often been dotted with debilitating externalities and trade-offs to the global economy, livelihoods, and environmental health. The main maritime shipping challenges are not independent stand-alone plinths; they are intrinsically connected at (i) the national and international levels, (ii) across the ocean system, and (iii) evolve with the increased lucrativeness of the industry. A challenge in one region or port can impact a network of actors in other countries or regions (18). Consider, for instance, the 2021 Suez Canal container ship obstruction, which shocked global trade and clogged most of the vital maritime arteries (19).

Additionally, complexities in freight data reporting and coding have remained prevalent. Attempts to harmonise shipping goods/services and the creation of a universally systematic coding system have been slow, and in some cases have even stalled (20). This has created customs clearance hurdles and hindered the efforts of international organisations, governments, and the private sector in enhancing fair trade negotiations, framing fair trade policies, monitoring controlled goods (such as protected species), determining freight tariffs, developing transport statistics, monitoring prices, and performing economic research and analysis. This is despite the creation of several mechanisms (such as the UN Central Product Classification, World Trade Organization services sectoral classification, and the International Monetary Fund's Balance of Payments Manual). Among port states, especially in emerging economies, piracy, non-flagged fleets, the operation of outdated or

low-tech fleets (partly due to the costs of hi-tech fleets), and trafficking have increased (21). Aboard fleets, increasing reports of declining safety standards, declining labour rights, sexual harassment, the exclusion of women seafarers, and sudden episodes of epidemics are also matters of concern. These pose ever-present threats and risks to global shipping trade, sustainability, and equity.

Recently, pressing environmental concerns, such as ballast pollution and climate change, have emerged. With the advent of novel technologies in ship designs, such as early warning systems that ensure equal buoyancy of ships, climate change need not have been a problem per se. However, it is associated with numerous impacts, such as strong ocean waves and sudden weather changes, including winds and typhoons, that have ramifications for the shipping industry. Climate change risks included delayed freight time, seasonal accidents, and distorted port infrastructure. These risks have led to an increase in instances of cargo loss or damage, reduced safety during berthing, loading, and discharge operations, and heightened risks associated with the carriage of deck cargo. Such issues have adverse ramifications for commercial laws, contractual rights, and a shipping firm's obligations to clients. Additionally, climate change-induced changes, such as swells and coastal flash floods, have partly led to harbour accidents, including capsizing of tankers. This has led to oil spills, biofouling, and the release of ballast, resulting in the introduction of invasive species and compromising the ecosystem health and biodiversity in the exclusive economic zones of several port states (22). Given these concerns, if no action is taken to mitigate climate change-induced risks and effects, significant damage, operational hiccups, and delays can be expected. These will significantly impact global supply chains, transportation and trade, contractual duties and liabilities, as well as insurance coverage, premiums, and risk disclosure requirements.

Towards Sustainable Shipping Transitions and Transformations

Recognising the perpetual and projected challenges in the shipping sector, a myriad of strategies for responsible and sustainable shipping have been advanced (23) including at the policy level through regulatory mechanisms to target specific challenges (24). To ameliorate the increasing carbon emissions, the International Maritime Organization has presented an ambitious strategy that aims to cut greenhouse gas emissions by at least 50 percent by 2050. This is premised on achieving net-zero emissions across the shipping value chain (25). Additionally, to promote maritime safety, the Global Maritime Distress and Safety System (GMDSS), a complement to globally recognised codes and conventions such as the International Convention for the Safety of Life at Sea and Convention on the International Regulations for Preventing Collisions at Sea, emphasises ensuring seafarers' safety and always utilising safe fleets (at ports and on seas) (26).

To amalgamate technological advances in shipping, collaborative efforts for digitalised shipping practices have been advanced (27). These include research on the utilisation of renewable energy in fleets and digital reporting and monitoring systems (28). For instance, Maersk, one of the world's largest shipping companies, has invested in methanol-powered vessels, with the first such ship delivered in 2023 (29). Wind-assisted propulsion systems, such as rotor sails and kite sails, are being tested by companies like Norsepower and Airbus to harness wind energy and reduce fuel consumption (30). Similarly, hull design improvements and air lubrication systems are being adopted to enhance vessel efficiency. Artificial intelligence (AI), data analytics, robotics, and automation are being used. For instance, companies like Rolls-Royce and others are developing autonomous shipping technologies that rely on AI to enable remote-controlled and fully autonomous vessels, which could further enhance efficiency and safety (31). Notably, the Port of Rotterdam has implemented a digital twin system that uses real-time data to optimise port operations and reduce emissions (32).

Conclusion

The shipping industry's journey toward sustainability is fraught with challenges, but is also brimming with opportunities. Technology and innovation will be the key drivers of this transformation, enabling the industry to reduce its environmental impact while maintaining its critical role in global trade. However, achieving sustainability will require more than just technological solutions. It will demand a collective effort from all stakeholders, including governments, businesses, and consumers.

KEY TAKEAWAYS

- The shipping and marine transport sector provides critical benefits, particularly ensuring sustained global trade. However, sustaining these benefits is becoming complex due to the increasing human-environmental risks associated with shipping and marine transport.
- Coastal states and regions, especially in the Global South, are the most affected by the changing dynamics in the shipping and marine transport sector.
- Mitigating the challenges in the sector necessitates collaborative actions, mechanisms, pathways, and frameworks. The success of such collaborations will heavily rely on the willingness of developed and emerging coastal shipping states to work together and ensure transparency and fairness in the shipping sector.

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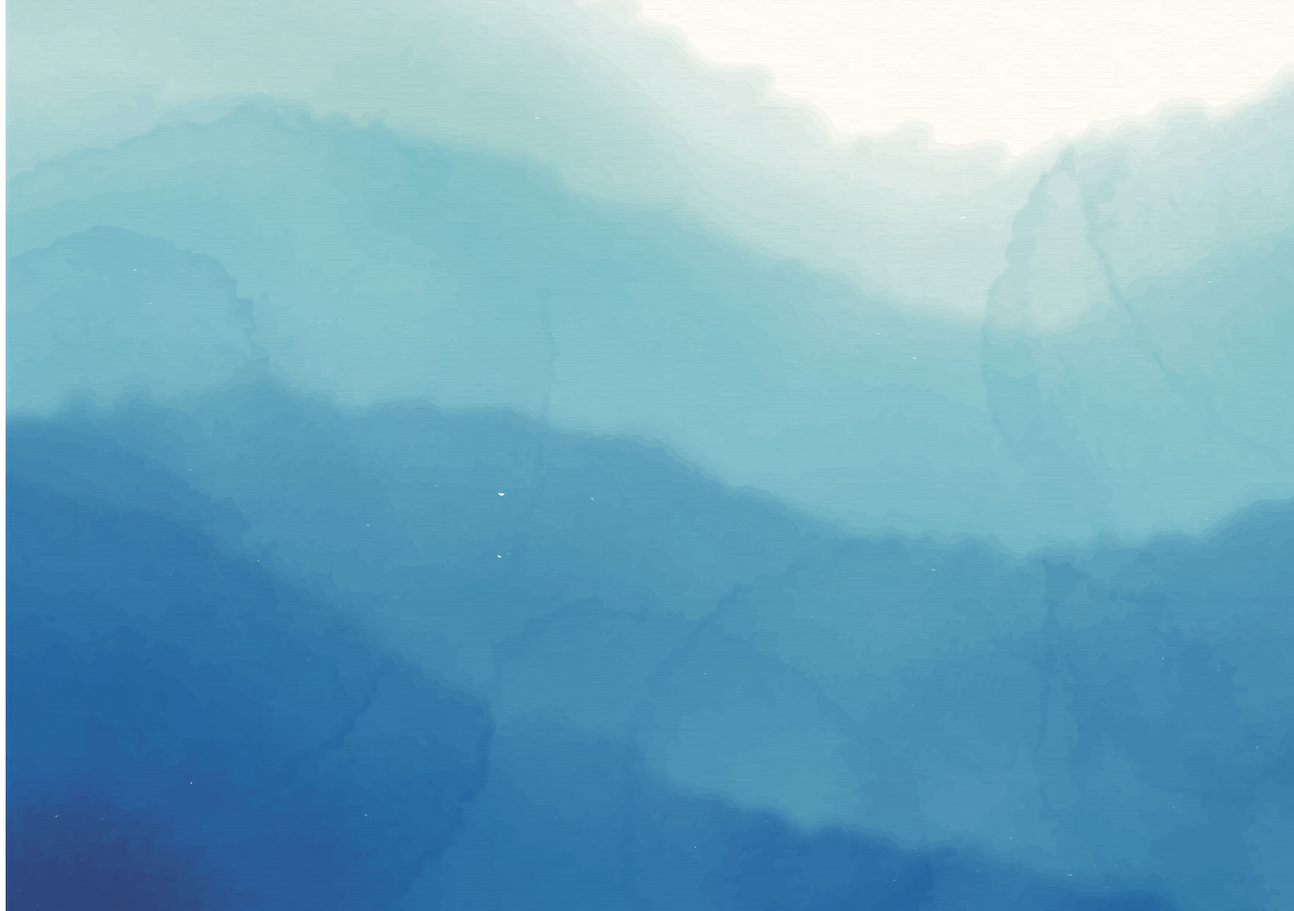
Disrupting Siloes: Why an Integrated Sustainability Framework is Imperative for Greener Shipping and the Blue Economy

Ayla Bajwa



Shipping is the silent engine of global trade, responsible for transporting nearly 80 percent of the world's goods across oceans (1). This vast maritime network has not only propelled globalisation but also exemplified human ingenuity in navigating complexity and embracing innovation.

As global populations surge and demand for goods intensifies, maritime transport—efficient, scalable and cost-effective—will continue to be instrumental in shaping sustainable economic development. Shipping remains the most carbon-efficient mode of freight transport: a very large container vessel emits merely 3g of CO_2 per tonne-km, compared to 435g for air freight (2).

Yet, this relative advantage belies a sobering reality: the sector's share of global CO_2 emissions, currently 2.9 percent, is projected to rise significantly in response to growing demand, potentially reaching 10 percent by 2050 (3).

Concurrently, the ocean—humankind's most vital natural asset—is under unprecedented threat. Land-based pollutants account for 80 percent of marine contamination, with plastic making up the lion's share (4). This deluge of waste is degrading fragile marine ecosystems and jeopardising biodiversity on a global scale. While the maritime sector is not the primary source, it is by no means exempt. The cumulative impact of oil spills, acoustic disturbances, and biofouling from merchant vessels represents a significant, if often overlooked, contributor to oceanic degradation (5).

These challenges are not discrete. Climate change, biodiversity loss, and marine pollution represent a convergence of systemic risks that demand—and indeed present a compelling economic case for—integrated, strategic action. Research commissioned by the Ocean Panel, an intergovernmental initiative, found that for every dollar invested in "key ocean actions", at least five dollars in global benefits could be realised by 2050 (6).

Yet, despite this return potential and the escalating risks to marine ecosystems, financing remains disproportionately low. 'Life below water', goal 14 of the UN Sustainable Development Goals (SDGs), faces an estimated annual shortfall of US$175 billion (7).

The Fragmentation Problem

Despite its centrality to global commerce, the maritime sector continues to operate within a fragmented sustainability landscape—one that fails to reflect the intricate interdependencies of the natural and economic systems (8).

Promising solutions are emerging; alternative fuels, advanced vessel designs and digital technologies offer immense potential. Yet, too often, these efforts are pursued in isolation. Siloed approaches, however well-intentioned, risk undermining the very progress they seek to achieve.

Consider, for instance, the development of new marine fuels. Without a comprehensive evaluation of their lifecycle impacts, such innovations may inadvertently introduce new ecological burdens (9). Green fuels are undoubtedly critical to decarbonisation. However, they must be integrated alongside investments in enabling infrastructure, biodiversity conservation, and resilient, inclusive economic models.

This lack of systemic alignment is not merely an oversight; it is a strategic vulnerability. The maritime sector cannot afford to pursue piecemeal solutions in the face of a planetary crisis. Even the most sophisticated technological advancements will fall short if they are not embedded within a coordinated, multistakeholder framework.

To be truly effective, the response must be holistic, adaptive, and inclusive—bringing together governments, port authorities, shipping companies, civil society, scientists, and financiers. It is only through such collective stewardship that one can ensure maritime innovation drives real, lasting impact, beyond emissions metrics, toward a thriving blue economy rooted in ecological balance and long-term prosperity.

The Innovation Imperative

In 2023, the International Maritime Organization (IMO) set a commendable course toward decarbonisation, adopting a revised strategy that mandates zero- or near-zero-emission fuels to contribute at least five percent—and ideally 10 percent—of total shipping fuel use by 2030 (10). Yet, despite the ambition of this directive, the global maritime sector remains off pace (11).

Closing the gap between aspiration and implementation requires more than policy mandates; it demands resolute leadership and market-driven momentum. Cargo owners and operators, as primary agents of demand, hold a pivotal role in steering the transition. The successful adoption of the IMO's net-zero framework hinges on proactive, cross-sectoral engagement and compliance with forthcoming regulations, including the establishment of a goal-based marine fuel standard.

At the heart of this transformation lies the challenge and opportunity of 'fuel innovation'. The shipping industry must decisively move away from traditional heavy fuel oils, which can contain up to 2,000 times more sulphur than diesel used in road transport (12). These fuels not only accelerate climate change but also cause serious harm to human health and marine ecosystems.

Emerging alternatives, such as ammonia, hydrogen, biofuels, methanol, wind propulsion and electrification, offer promising pathways. Yet, each solution is accompanied by complex trade-offs, ranging from safety and cost to supply chain viability and infrastructure readiness (13).

Encouragingly, strategic alliances are beginning to form. DP World, for instance, has partnered with AM Green in India to develop infrastructure capable of exporting one million tonnes each of green ammonia and methanol annually (14). This initiative includes major investments in port facilities across Europe and Asia.

Research partnerships such as the Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping and collaborations with Pacific International Lines are also advancing the science, scalability, and commercial viability of alternative fuels. These collective efforts signal a turning point, yet the pace must quicken, and the ambition must widen.

The Biodiversity Factor

In the global drive to decarbonise, biodiversity has too often been relegated to the background, an afterthought in strategies that prioritise carbon metrics over ecological resilience. This must change. The health of the planet is not defined solely by carbon levels, but by the vitality of the ecosystems that sustain life and regulate the climate.

Mangroves, seagrass meadows, and salt marshes are among the most powerful natural carbon sinks on Earth, storing between 10 and 100 times more carbon than terrestrial forests (15). They also serve as buffers against storm surges and are essential breeding grounds for marine species, supporting both biodiversity and coastal resilience.

Yet, these ecosystems are disappearing at an alarming rate (16). Coastal development, pollution, and climate-induced stressors are eroding their capacity to store carbon, protect shorelines, and nurture life. The proximity of the shipping industry to these environments places it in a position of unique responsibility and opportunity.

Leading by example, DP World's Blue Carbon Ecosystems Strategy is creating a regenerative legacy by investing directly in nature. In Ecuador, the Sembrando Vida project at DP World's Posorja terminal has planted over 250,000 mangroves since 2017, sequestering more than 50,000 tonnes of CO_2 while supporting hundreds of local livelihoods (17).

Further partnerships, such as DP World's work with Living Seawalls, are transforming traditional port infrastructure into nature-positive assets. These habitat panels, designed to mimic marine ecosystems, not only restore biodiversity but also pioneer new models for sustainable engineering. Such projects demonstrate that ecological sensitivity and infrastructure development need not be at odds. In fact, they can and must be mutually reinforcing.

Without careful biodiversity assessments embedded from the outset, even well-meaning decarbonisation infrastructure can become a source of unintended environmental harm. This trade-off must be rejected. True leadership requires advancing both climate action and biodiversity protection in tandem.

The Finance Factor

The transition to a low-carbon, nature-positive maritime economy will not be realised without financial innovation. Capital must flow not only toward new fuels and technologies, but also toward the ecosystems and communities that underpin the maritime sector's long-term sustainability.

This begins with redefining how risk and value are measured. Current investment models often fail to account for the systemic risks posed by climate change, biodiversity loss, and ecosystem collapse. Likewise, they

undervalue the long-term economic returns of resilience, regeneration, and resource efficiency. It is time to recalibrate the metrics, incorporating nature and social outcomes into mainstream financial decision-making.

A powerful example of what is possible is DP World's US$100 million Blue Bond issued in 2024, the first of its kind in the region. The bond finances projects spanning marine transport, sustainable port infrastructure, and marine ecosystem restoration, all aligned with SDG-14 and the principles of integrated sustainability.

Similarly, in Southeast Asia, a blue bond issued with support from the Asian Development Bank enabled the retrofitting of domestic cargo vessels with green ammonia-compatible engines, while also funding mangrove restoration along strategic coastal shipping routes (18).

Crucially, unlocking the full promise of the blue economy will depend on the willingness to reimagine finance itself. Novel instruments, such as blue bonds, must not only fund innovation but also embed ecological value into their financial logic. Only by aligning economic incentives with environmental outcomes can one generate the kind of systemic, scalable change required to restore ocean health, empower communities, and secure sustainable growth for generations to come.

The Way Forward

The time for incrementalism has passed. What the maritime sector needs now is a paradigm shift, one that places systems thinking at the core of innovation, investments, and governance.

It is time to move beyond fragmented strategies and instead embrace a bold, integrated framework that aligns decarbonisation with biodiversity conservation, inclusive development, and long-term economic resilience.

Ports are the nerve centres of this transformation. With their unique ability to convene stakeholders—shipping lines, logistics firms, regulators, and communities—they must become hubs of sustainable innovation and environmental stewardship.

The blue economy represents one of the greatest opportunities—to decouple growth from environmental harm and to redefine what leadership looks like in the 21st century. Humankind already has the science, technology, and capital. What is required now is conviction, coordination, and courage.

KEY TAKEAWAYS

Shipping's environmental challenges are interconnected: Addressing emissions, biodiversity loss, and pollution requires an integrated sustainability framework.

Innovation alone is not enough: Accelerated collaboration among stakeholders is essential to scale up green fuels, infrastructure, and biodiversity conservation.

Unlocking the blue economy demands financial ingenuity: Novel financial instruments must align economic incentives with ecological outcomes to fund meaningful change at scale.

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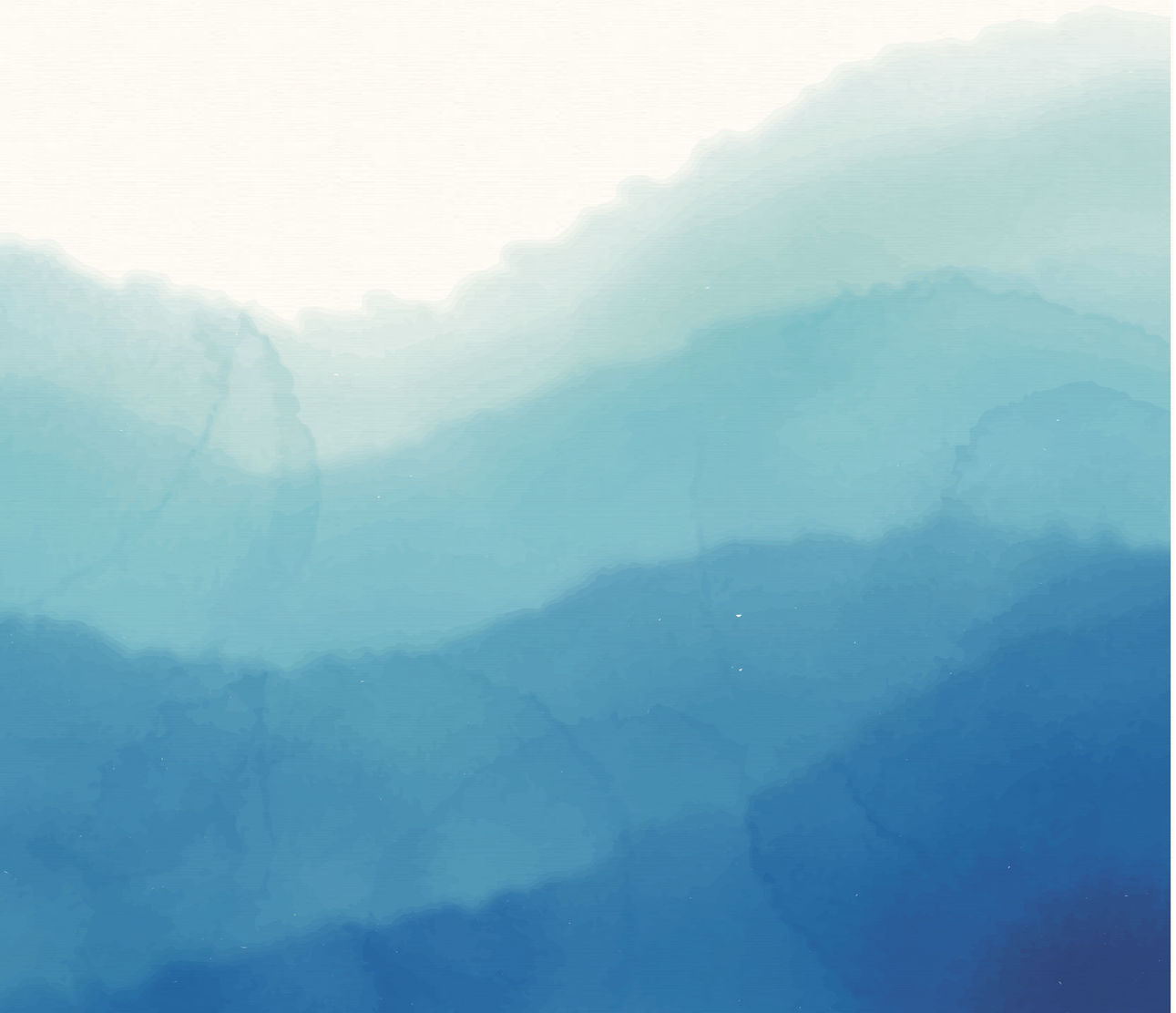
The Path to Decarbonising the Maritime Industry

Nwabisa Matoti



The oceans comprise about 70 percent of the planet (1) and are a source of food security, survival, and livelihood. The need to protect and conserve the oceans and their resources is therefore critical to enable the sustainable use by future generations. This highlights the importance of the green and blue economy. The green economy refers to, among others, aspects relating to climate change (by reducing carbon emissions to preserve the oceans), the efficient utilisation of natural resources, waste reduction, and the protection of the environment from degradation (2). The blue economy, on the other hand, refers to the sustainable use of the ocean utilising innovative and environmentally friendly practices, infrastructure, and technologies to promote the protection of the coast, the oceans, and the welfare and livelihoods of coastal communities, thus reducing marine resource scarcity and environmental risks (3).

The difference between the blue and green economy, therefore, is that the green economy largely focuses on low-carbon and resource-efficient activities, while the blue economy focuses on environmental preservation and community welfare (4). While preserving marine life is a crucial part of the blue economy, protecting the livelihoods and cultures of coastal communities is equally important. This will thus require formulating regulations and policies that influence the sustainability of the oceans and marine resources.

In recent years, the shipping industry has shown a growing interest in adopting sustainable management practices to reduce the carbon footprint of maritime shipping. The emission of greenhouse gases is considered a major contributor to climate change that can have a negative impact on the lives and livelihoods of communities (5). Shipping emissions represented about 2.89 percent of global emissions in 2018, up from 2.76 percent in 2012 (6). As such, the International Maritime Organization (IMO) has set ambitious targets to reduce emissions in shipping to 20 percent by 2030, 70 percent by 2040, and net-zero emissions by 2050 (7). This requires joint efforts by countries to address decarbonisation in maritime transport.

Need for Decarbonisation in the Maritime Shipping Industry

As ships typically have a 20–40-year lifespan, decarbonisation has largely been premised on ensuring existing ships adapt to emission control regulations by installing new equipment, and developing new low-emission fuels and

infrastructure to produce those fuels (8). In addition to regulatory requirements, the IMO recommends using alternative fuels, such as hydrogen and liquefied natural gas, and developing technologies to decrease fuel consumption in maritime shipping (9). Furthermore, there has also been growing interest in synthetic fuels, such as ammonia and methanol, and blue fuels derived from treating carbon-containing gases such as CO or CO_2 (10).

Although efforts have been made towards decarbonisation across various industries, certain sectors, such as the maritime shipping industry, are deemed more difficult to decarbonise and referred to as hard-to-abate sectors (11). This can be attributed to the long lifespan of the ships, which can result in a slow phase-out of the current fleet with higher emissions, as well as the long lead time in the production and deployment of low-carbon fuels. However, a few large shipping companies have already placed their first orders for low-carbon fuel ships (12). The primary focus areas for achieving the most CO_2 emission reductions are fuels and alternative energy sources, power and propulsion, speed, hull design, and weather routing and scheduling (13).

Ports have also adopted decarbonisation measures, including providing alternative fuels to ships and tracking energy consumption and GHG emissions. Other measures include reducing vessel speed, slow steaming from ships, and just-in-time berthing or berth scheduling, which can significantly reduce carbon emissions through rationalised fuel consumption (14). The Port of Barcelona, for instance, implemented a medium-voltage network that enables vessels to connect to an electrical source in the port, reducing the reliance on combustion engines when docked (15). Similarly, the Port of Los Angeles has implemented measures for efficient cargo transfer (16), while the Port of Antwerp has implemented carbon capture and reuse methods (17).

However, sustainability considerations in maritime shipping may involve conflicting objectives, such as the commitment to minimising fuel emissions while maximising service levels (18). Handling these multiple objectives, therefore, may require using an information system that determines the optimal results based on different scenarios and makes adjustments to find the best strategies to ensure compliance with maritime transportation regulations whilst maximising company performance.

Implementing Decarbonisation Measures

To promote the effective implementation of decarbonisation measures in the maritime shipping industry, the following factors should be considered:

- **Technology**

The maritime transport industry is constantly evolving due to growing demands for safety, efficiency, and sustainability, resulting in the development of new technologies that enable the industry to remain competitive. New technologies in the maritime industry include artificial intelligence, autonomous ships, blockchain, Internet of Things (IoT), marine robotics, advanced communications systems, new materials, virtual reality, and augmented reality (19). Using these technologies is expected to improve the efficiency of maritime operations significantly. The IoT can encompass ocean stations, buoys, sensors, satellites, and aerial remote sensing, thereby generating useful maritime Big Data through a single platform (20). Furthermore, the development of smart ports enables real-time communication, monitoring, and data sharing between the various aspects of the industry. This, therefore, contributes to smart shipping (a system of connecting ports and ships for efficient decision-making) and to reduced ecological footprints and costs, based on smart infrastructure and maritime intelligence (21).

- **Training and skills development**

The successful implementation of sustainability measures and new technologies to address GHG emissions from shipping requires a skilled workforce. There is a need to identify the skill sets required to address the current and future needs of the industry with respect to decarbonisation and sustainability initiatives. Future skills that may be required in the shipping industry may be focused on problem-solving, and social and cognitive abilities (22). The training of seafarers on the workings of vessels that utilise alternative fuels and new technologies, including the remote operation of autonomous vessels, is critical. Furthermore, the capacity of academic institutions and vocational centres to offer the required skills needs to be assessed, with proposed interventions to address the gaps, including through the development of modules, sourcing of infrastructure and equipment to support the learning, or the implementation of train-the-trainer programmes.

- **Investment and financing**

Significant investments in pilot decarbonisation projects, as well as research and development, will be required. Financing mechanisms, including commercial finance, developmental finance, and donor or grant funding, should be considered to fund these initiatives. Governments can also consider providing financial incentives (such as tax breaks, subsidies, and grants) and funding to encourage investment in new technologies (23).

- **Collaboration and partnerships**

Key to the successful implementation of the new technologies and projects is collaboration between different stakeholders in the maritime transport industry, including ports, shipowners, logistics companies, technology providers, and regulators (24). Partnerships with research institutes, universities, and vocational centres to share knowledge and resources should also be considered. This will also promote the pooling of resources and knowledge to achieve sustainability goals in maritime shipping.

Conclusion

Increased efforts are necessary to reduce carbon emissions in maritime shipping to combat the negative impacts of climate change. This requires the construction of vessels that utilise alternative fuels and energy sources and the development of new technologies. Therefore, governments, the maritime industry, and the relevant stakeholders need to devise strategies to promote technological innovation, decarbonisation, and sustainability in the maritime shipping sector. Comprehensive long-term planning, including action plans, timeframes, and costing, is required, serving as a roadmap for implementing efficiency and decarbonisation measures in the maritime industry.

KEY TAKEAWAYS

The impacts of climate change are evident in the significant shifts in weather patterns and temperatures worldwide. As such, sustainability efforts to deal with carbon emissions must be expedited.

Decarbonisation is a necessity that should be prioritised by all sectors of the economy, including maritime shipping.

Training, capacity building, improved technology, increased investment, and enhanced collaboration are the key enablers that should be considered in implementing decarbonisation measures in the maritime shipping industry.

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Advancing Sustainable Circularity in Ship Recycling: A Pathway to Occupational Health and a Green Transition

Paritosh Deshpande and Yogindra Samant

The global ship recycling industry is poised for significant expansion, with an estimated 10 to 15 million tonnes deadweight of vessels expected to be decommissioned annually over the next decade (1). This surge is driven by the natural ageing of fleets and by unplanned obsolescence, as increasingly stringent environmental regulations, rapid technological advancements, and modern ship designs render operational vessels redundant (2). Consequently, the demand for adequate infrastructure to dismantle these ships is projected to rise globally, necessitating sustainable solutions that balance economic viability, environmental responsibility, and worker safety.

India occupies a central position in the global ship recycling industry, with Alang-Sosiya in Gujarat representing the world's largest ship dismantling hub. The region's unique geographical characteristics—including a high tidal range (~13 metres) and a gentle beach slope (~10°) underlain by stable bedrock—facilitate the efficient beaching of vessels for manual dismantling (3). Beaching remains the predominant ship recycling method in South Asia. Alternative dismantling approaches include dry docking and using floating platforms, but despite methodological differences, the core processes and associated environmental and occupational hazards remain largely comparable across different shipbreaking techniques (4). Ship recycling plays a crucial role in the circular economy (CE) by recovering valuable materials, including steel and non-ferrous metals, from decommissioned vessels (5). However, the industry's reliance on traditional dismantling methods poses significant environmental and occupational health risks. The uncontrolled release of hazardous substances—such as asbestos, heavy metals, and persistent organic pollutants (6)—has raised concerns over worker safety and marine pollution, prompting calls for regulatory reforms and technological advancements to foster safer and environmentally responsible recycling practices.

Regulatory frameworks have evolved to address these challenges. The Gujarat Maritime Board has overseen ship recycling operations in Alang for over two decades, implementing key regulations, such as the 2003 Ship Recycling Safety and Hazardous Waste Management Regulation and the 2006 certification framework for the renewal of ship recycling plots (7). At the international level, the adoption of the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships (HKC) in 2009 marked a significant step towards establishing uniform global standards. The Convention mandates improved hazardous waste management, enhanced worker protections, and stricter regulatory oversight (8). India's accession to the HKC, along with the enactment of the 2019 Recycling of Ships Act, represents a substantial step towards aligning domestic regulations with international environmental and occupational safety norms (9). However, challenges persist in ensuring compliance, strengthening worker protection mechanisms, and effectively implementing health, safety, and environmental (HSE) standards.

As India seeks to expand its shipbuilding and recycling capacity while adhering to sustainability principles, international collaboration will be instrumental in driving progress. Countries with advanced maritime expertise, such as Norway, can play a critical role in facilitating technology transfer, capacity building, and the development of circular business models within the sector. This essay explores the opportunities for advancing sustainable ship recycling in India, highlighting potential international partnerships and outlining pathways to enhance environmental performance, workplace safety, and economic resilience within the industry.

Circular Economy and the Sustainability Perspective

The CE is widely regarded as a key strategy for achieving sustainability by promoting resource efficiency and waste reduction (10). However, an overly unidimensional focus on CE targets may lead to counterproductive outcomes, including greenwashing—where practices appear environmentally responsible but fail to address broader sustainability concerns. True sustainability necessitates a comprehensive balance between environmental, social, and economic dimensions, often in tension with one another (11). This complexity is particularly evident in the ship recycling industry, which contributes to CE, but challenges persist regarding worker and environmental safety. Table 1 shows the associated benefits and threats of the ship recycling activity across the environmental, social, and economic sustainability criteria.

Table 1: Environmental, Social, and Economic Impacts of Current Ship Recycling Practices

Criteria	Benefits	Barriers
Environment	• Resource conservation, recycling, upcycling, repair, and reuse of materials • Reduced carbon emissions through circular management	• Exposure to hazardous waste • Pollution of land, air, and water around recycling yards
Social	• Employment opportunities for both skilled and unskilled labour • Revenue from EOL vessels	• Increased health risks to the work environment • Inequalities in occupational health and societal safety
Economic	• Increased value of upcycled materials • Economic value from end-of-life vessels	• Vulnerability to fluctuations in steel prices • Social and health costs

Source: *Authors' own.*

Ship recycling is an integral part of the CE, enabling the repair, reuse, upcycling, and remanufacturing of end-of-life (EOL) vessels, thereby reducing the demand for resource extraction. In the Alang-Sosiya yards, approximately 98 percent of ship materials are sold in secondary markets, demonstrating a strong waste-to-value model (12). Although ship recycling exemplifies CE, it also presents occupational and environmental risks. Sustainable practices must balance value recovery with worker safety and environmental integrity. A lifecycle perspective in ship design, known as 'prevention by design,' can integrate recycling considerations from the outset. This approach reduces hazardous waste, minimises health risks, and fosters sustainable EOL management. Achieving sustainable circularity requires systemic collaboration among vessel designers, builders, users, and recyclers.

The Future: Advancing Sustainable Circularity in India's Ship Recycling Sector

Advancing sustainable ship recycling in India requires technological innovation, strategic partnerships, and socioeconomic considerations (13). Addressing global occupational health inequalities in the industry aligns with goal 17 of the Sustainable Development Goals (SDGs), emphasising collaboration. Strengthening cooperation between developed maritime nations and South Asian ship recycling hubs can drive systemic improvements in environmental and occupational health standards.

With its strong maritime heritage, Norway excels in ship design, technological innovation, and sustainable solutions, including autonomous and fuel-efficient vessels. Norwegian shipyards have gained a competitive edge through a strong commitment to occupational health and safety regulations and extensive research and development in maritime technology (14). By intensifying cooperation with ship recycling nations such as India, Norway—alongside regulatory bodies, research institutions, HSE experts, international organisations (such as the International Labour Organization and the International Maritime Organization), and social partners—can contribute to the development of safer, more sustainable recycling practices. A particularly promising avenue for collaboration is co-learning between ship designers, shipbuilders, and recyclers. Traditionally, shipbuilders have prioritised functionality and longevity over considerations for CE upon EOL disposal. However, greater engagement between designers and recyclers could lead to innovations in ship design that prioritise CE principles, such as 'design for recycling', 'design for circularity' and 'risk prevention by design'. By incorporating insights from Indian ship-recycling yards, designers can develop ships that are easier to disassemble, repurpose, and recycle.

A second initiative could focus on Norway-India collaboration in upcycling materials from EOL vessels at Alang-Sosiya. Recovered steel and other materials could be repurposed into low-intensity vessels for inland and regional maritime use. Applying advanced shipbuilding techniques from Norwegian shipbuilders to recycled materials will enhance resource efficiency, generate economic value, and support localised ship production in India. A pilot project in this area could be a flagship for sustainable and circular shipbuilding, ensuring compliance with environmental, social, and economic sustainability criteria while strengthening India's vessel manufacturing capabilities.

Building on the 2019 Memorandum of Understanding between Norway and India, which aims to foster strategic cooperation on ocean governance, future initiatives could encompass capacity-building programmes, technology transfer efforts, and certification schemes to establish and enforce internationally recognised HSE standards in ship recycling. Strengthening regulatory oversight and supporting infrastructure development in India, Pakistan, and Bangladesh could improve occupational health disparities in the sector.

Ultimately, a just and green transition in global ship recycling has the potential to drive long-term improvements in sustainability, worker protection, and CE practices. By aligning ship recycling efforts with the broader framework of SDG-3 (good health and well-being), SDG-8 (decent work and economic growth), SDG-12 (responsible consumption and production), and SDG-17 (partnerships for the goals), such initiatives can contribute to a sustainable global maritime industry.

KEY TAKEAWAYS*

Holistic sustainability in ship recycling: Ship recycling supports the CE, but a balanced approach is necessary to prevent greenwashing by addressing social sustainability alongside economic and environmental benefits.

International collaboration for innovation and co-learning: Global partnerships, such as between Norway and India, can drive technology transfer, capacity building, and circular business models, integrating 'design for circularity' principles to enhance recyclability and minimise occupational health risks.

Strategic partnerships for local value creation: A collaborative approach across the ship's lifecycle—engaging designers, builders, operators, and recyclers—can improve resource efficiency, create economic value from waste, and promote localised ship production in India.

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**Disclaimer: The authors used Grammarly to refine and condense the takeaways. The original pointers were their own creations, and Grammarly was utilised only to shorten these while adhering to the essay word limitations. No new ideas or content were generated using AI.*

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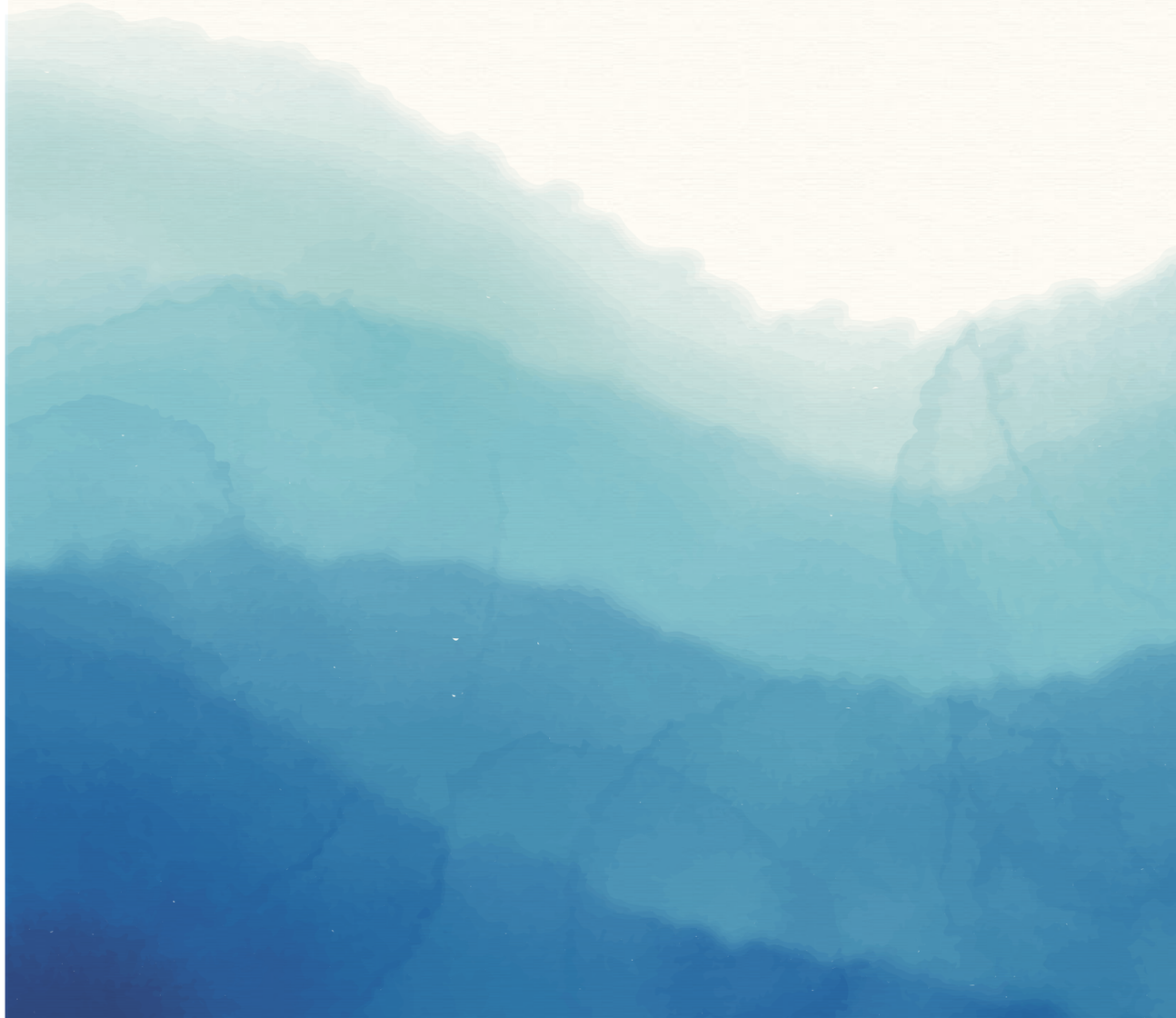
Maritime Technology and Innovation: Charting the Future

Tanuja Kaushik and Rahul Akolkar



Maritime transportation accounts for approximately 70 percent of the value of global trade, as the majority of high-value commercial commodities are containerised, and around two-thirds of this share is transported by containers (1). Advancements in marine technology have played a key role in the growth of maritime freight traffic, enabling lower costs in larger ships across various areas, including crew wages, fuel, insurance, maintenance, and other operational expenses (2). This requires port officials to enhance port access (by deepening fairways) and expand port infrastructure, including wharfage and inland transit connections, to address the challenges posed by growing vessel sizes (3).

Most Indian ports owned and operated by the government require substantial upgrades due to their ageing infrastructure, which hampers their ability to efficiently manage increasing cargo volumes and meet the demand for swift turnaround times (4). Limited infrastructure, congestion, poor hinterland connectivity, and outdated cargo-handling equipment delay loading and unloading, thereby reducing vessel efficiency. Additionally, some ports cannot accommodate large ships, forcing them to anchor offshore while requiring barges or smaller vessels to transport cargo to and from the port (5).

Navigating Innovation Challenges in Indian Ports and Infrastructure

Globally, port operators stack containers five to six tiers high, reducing efficiency when yard occupancy exceeds 80 percent (6). This impacts landside operations and complicates equipment dispatch due to interdependent processes. Manual crane operation and frequent diesel maintenance lower efficiency, increase CO_2 emissions and noise, and make infrastructure expansion costly and time-consuming (7). Global container ports have routinely experienced disruptions. For instance, the expansion of the Panama Canal (8), aimed at enhancing global maritime trade, has encountered challenges such as lower aggregate demand and misconceptions about its ability to generate additional trade. Similarly, African ports (9) along the Red Sea face disruptions due to security crises, leading to decreased vessel calls and operational inefficiencies. In Latin America (10), outdated port infrastructure and insufficient equipment hinder the region's integration into global supply chains. Addressing these challenges is essential for improving trade efficiency and fostering economic growth across these regions.

If applied to Indian ports, particularly major brownfield ports like Mumbai's Jawaharlal Nehru Port (JNP), Chennai Port, Kandla Port, and Kolkata Port, four key challenges (11) emerge: large yard footprints leading to rearrangement issues; unpreparedness for ultra-large container carriers, hindering economies of scale; pressure for densification; and concerns regarding safety and environmental impacts (12).

The universally accepted 'global standard' for container moves per hour ranges from 100 to 150, even at the most advanced terminals (13). Even if a port operates for 20 hours daily, this translates to 2,000 to 3,000 container movements daily. However, Chennai Port's Chennai Container Terminal Limited falls short of these standards, with a single quay crane handling only 600 container movements daily. Even with eight quay cranes in operation, only 4,800 containers are moved, significantly below global benchmarks (14).

Innovation in the Maritime Sector: Trends and Opportunities

Indian ports are gradually adopting automation and advanced technologies, improving efficiency with smoother cargo handling, and promoting sustainable energy initiatives. For instance, Vizhinjam Port in Kerala, India's first fully automated greenfield port, has recently begun operations with the capacity to handle megamax (15) container ships and ensure fast vessel turnaround (16). Moreover, the Unified Logistics Interface Platform (ULIP) (17) for ports is a digital initiative under India's National Logistics Policy. This integrated system aims to assist stakeholders in comprehensive logistics planning while streamlining and integrating logistics across the supply chain (18).

Despite steady growth in the cargo handling capacity at the major ports, the average capacity utilisation remains around 49.1 percent as of FY23 (19), highlighting the need for improvement. Most major ports in India are brownfield and require significant upgrades, even in container handling technologies. Ports like the JNP and Chennai face issues such as congestion, large yard footprints, outdated technology, and inadequate infrastructure, reducing competitiveness and capacity utilisation (20).

Conventional stacking in container yards along the berth side of terminals has been the norm for decades (21), typically reaching five to six storeys for both import and export storage. However, this leads to larger yard footprints, and when ultra-large container carriers or Supramax vessels arrive, efficiency tends to decline once yard usage exceeds 80 percent (22).

To address these concerns, Indian ports should explore advancements in container handling technologies to enhance efficiency and optimise operations. For instance, the European Union-funded Robotic Container Management System (23) project aims to enhance efficiency at European ports constrained by limited space and high land costs by deploying advanced robotic systems to maximise storage density while ensuring direct access to each container. There are approximately 40 semi- or fully-automated container terminals in operation worldwide, reflecting a growing trend in terminal automation. These innovations enhance efficiency by increasing movement frequency and reducing unnecessary cargo handling through the use of automated equipment in ship-to-shore transfers, yard operations, ground transportation, and gate automation, ensuring consistency and minimising container downtime (24).

On the other hand, innovations like BOXBAY (25), a high-bay storage system currently implemented by AMOVA and DP World under a pilot project at the Jebel Ali Port (26), allow containers to be stacked individually up to 11 storeys, significantly reducing yard footprints and alleviating space constraints. Minimising container and yard shuffling enhances efficiency and accelerates the transfer of containers from the yard to the quay, enabling faster loading and unloading for megamax containerships (27).

Innovation and Adaptability: The Way Forward

As global trade expands, port efficiency and safety have become critical concerns for the maritime industry. Traditional container handling methods often face challenges related to space constraints, engine emissions, unreliable yard activities, operational delays, and safety risks. For instance, being fully automated, BOXBAY can meet every terminal handling need, significantly enhancing safety by eliminating manual operations. Additionally, separating traffic from the quay further enhances the overall safety environment with a significant increase in yard capacity, alleviating the tension for densification and space constraints (28). Automation is another key innovation in container management, with robotics and automated systems optimising handling, sorting, and loading. Moreover, automated cranes and conveyors boost efficiency, cutting labour costs and errors. For a non-vessel operating common carrier (29), this means faster turnaround, lower costs, and higher throughput.

Conclusion

As the maritime industry continues to evolve, upgrading port infrastructure and adopting innovative solutions will be essential to enhancing efficiency, safety, and sustainability. With its growing trade volumes and strategic location, India has the potential to lead the way in port modernisation. By investing in advanced container handling technologies and optimising terminal operations, India can set new global benchmarks, strengthen its position in global shipping, and drive the future of smart and efficient port management.

KEY TAKEAWAYS

Embracing technological advancements: Staying ahead of trends and adopting innovations is essential for port operators to remain competitive and deliver high-quality service.

Optimising space and efficiency: Solutions such as the Robotic Container Management System and BOXBAY, and automation in container handling can help mitigate space constraints, improve container utilisation, and enhance terminal operations.

Meeting evolving industry demands: Advanced port technologies will play a crucial role in addressing the growing challenges of the shipping industry by streamlining operations and increasing overall efficiency.

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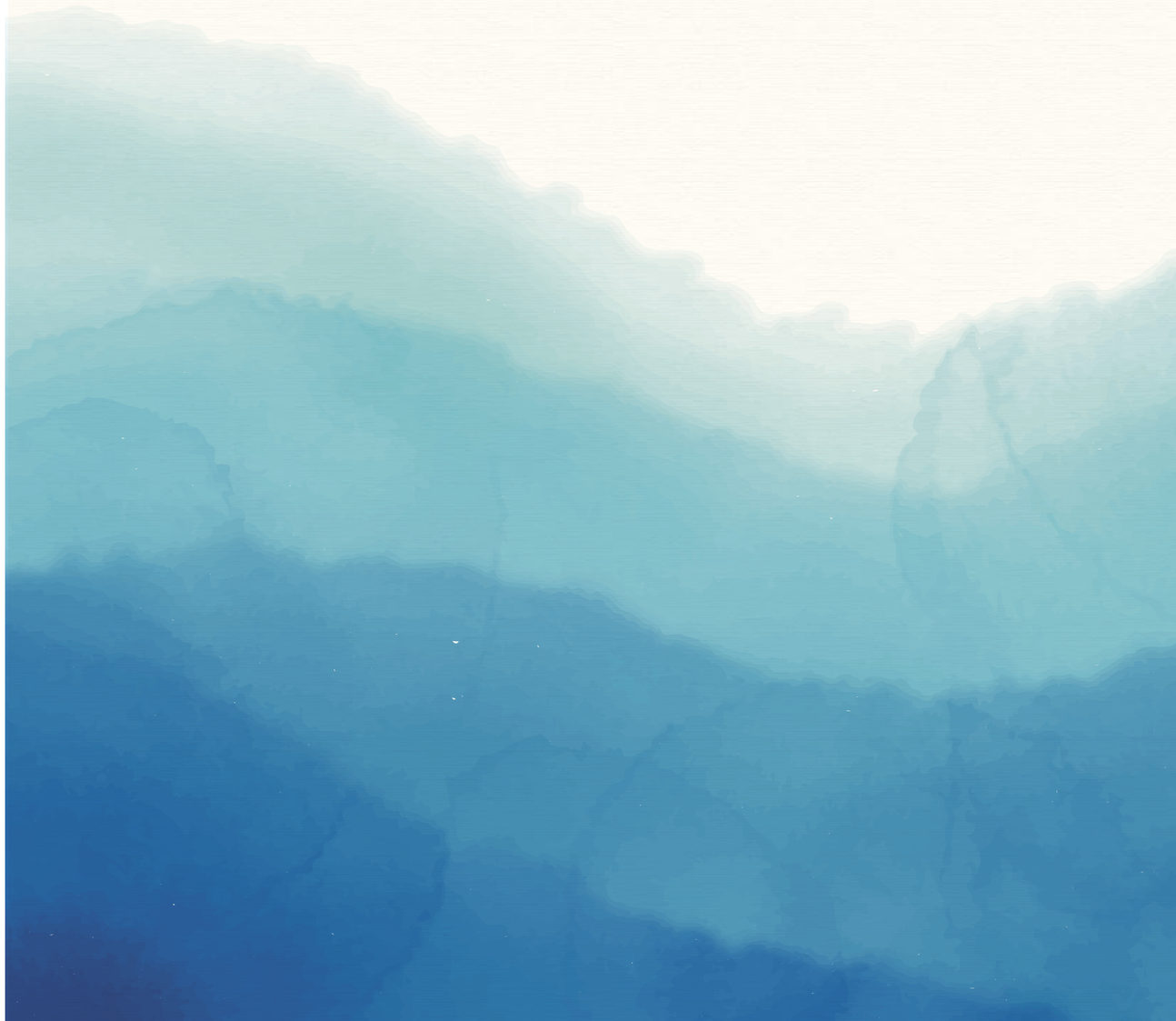
Inland Shipping in the Netherlands: On the Way to Zero Emission

Nicole van Spronsen



Inland water transport (IWT) is a sustainable and effective way of transporting goods from the Netherlands' harbours to and from Europe's hinterland. Cargo transported by water accounts for about 40 percent of the total transport volume (1), and this transport is essential for the hinterland industry zones to produce and deliver their goods. Given that IWT is connected to the sailing routes worldwide and has access to green technologies, the industry has significant potential to organise IWT in an even more sustainable way. However, this transport mode has to be reliable at all water levels.

The Dutch Scenario

The Netherlands is situated on the Rhine River and the Meuse River Delta, which discharges into the North Sea and is connected to the ocean (2). The inland waterways are navigable through dredging and a limited number of locks (3). The main transport network spans approximately 1,400 km (4), including smaller fairways. Cargo from the main ports of Rotterdam and Amsterdam is easily transported through Europe by IWT ships (5). In the opposite direction, hinterland goods (for example, from Germany) are transported through the Dutch waterways, which are accessible for global transport.

Figure 1: The Dutch Inland Waterways System

Note: *big blue dots are > 10 million tonnes per year; white dots are > 3 million tonnes per year; green dots are < 3 million tonnes per year; small blue dots are < 2 million tonnes per year.*
Source: *Bureau Voorlichting Binnenvaart (6).*

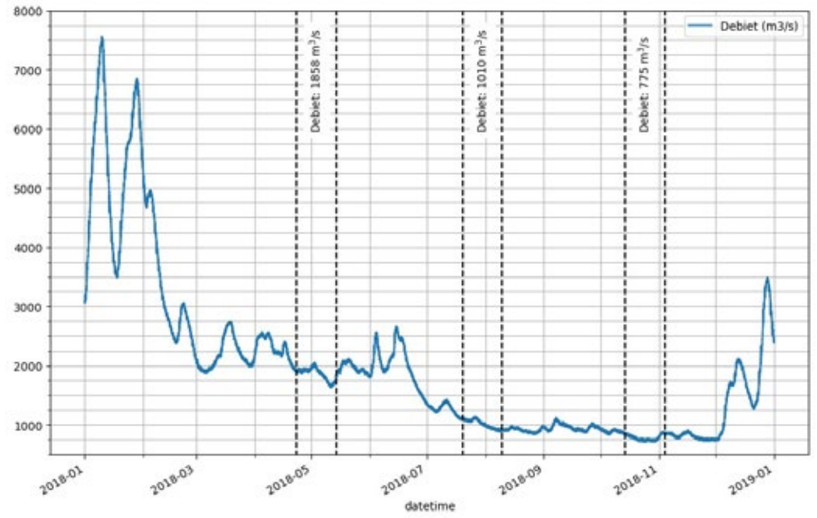
The Netherlands has the largest fleet in Europe, with over 8,000 IWT ships (7). There are various ship types, ranging from 10,000 to 350 tonnes (8). Roughly half of the professional fleet is owned by the captain and their family, and may also be their family home; however, several shipping companies now own multiple ships and hire the skippers as employees (9).

To meet the European Green Deal obligations to make the European Union climate-neutral by 2050 (10), the IWT system will need to reduce emissions. Inland shipping is already a low-emission mode of transport compared to road transport, largely due to its lower cargo volumes (11). Achieving climate-neutral and emission-free inland shipping by 2050 is possible with cleaner engines, new technologies (such as sailing on batteries and hydrogen), and the retrofitting of existing engines (12). The use of after-treatment techniques on existing engines to meet the emission requirements is a possibility (13). However, most ship-owning families do not have the financial capabilities to realise expensive zero-emission retrofit solutions and depend on government subsidies (14).

The Climate Change Threat

The Dutch Ministry of Infrastructure and Water Management is responsible for maintaining and ensuring the navigability of the river system (15). The system depends on rainfall and melting water. However, due to climate change, there are often extreme dry periods with less water in the rivers as well as extreme wet periods resulting in higher water levels (16). Discharge resulting in the river water level is measured in cubic metres per second (debiet) when entering the Netherlands through the Rhine River near Lobith (17). Figure 2 shows the situation in 2018 where the water level was extremely low with an average debiet of below 1000 m3/s while the normal discharge is 1800 m3/s. While the 2018 situation was an exceptional phenomenon, an extreme low water period was also recorded in 2022 (18).

Figure 2: Discharge (m3/s) at Lobith Resulting in Low River Water Levels in 2018



Source: *MARIN (19).*

Dry periods restrict the cargo volume each ship can carry to ensure the ability to sail with a reduced draft (20). The safe and sound cargo transport per ship is challenging during dry periods. In 2018, MARIN, the Maritime Research Institute Netherlands, studied the relationship between fuel consumption and emissions at different water levels for a complete fleet on a specific trajectory (21). This addressed the question of how climate change affects IWT in terms of sustainability and transport efficiency at different water levels. A notable finding was that at extremely low water levels, fuel consumption and emissions per tonne of cargo increased 225 percent compared to normal water levels (assuming constant tonnage) (22).

Due to climate change, extreme water levels, both low and high, occur more often and persist for longer durations (23). As such, the Netherlands' IWT sector needs workable solutions to become more climate-resistant.

Battling Climate Issues

An important contribution to improving the environmental performance of the transport sector is through a modal shift—moving cargo flows from road to water. A prerequisite for this is the reliability of the IWT sector, even at low water levels. New ship designs to ensure reliability in varying conditions are improving the success of the modal shift. Specialised low-water ships with extra light materials, multiple small-dimension propellers, or other innovative solutions are under investigation (24).

The Dutch Maritime Masterplan is a subsidy programme by the Dutch government to build 30 zero-emission demonstration ships by 2030 (25). The aim is to bridge the gap between research and large-scale production for a future-proof, sustainable maritime industry. Building and sharing the knowledge of innovative systems, designs, and techniques is an important pillar. Cooperation within the Netherlands' marine industry is a key factor. Among the first nine approved projects, five new inland waterway concept vessels are being built to demonstrate that zero-emission IWT is possible and scalable (26). This highlights the crucial role of IWT as a sustainable and reliable mode of transport.

Conclusion

IWT is vital to the Netherlands' logistics network, offering a sustainable alternative to road and rail transport. However, climate change threatens its reliability with fluctuating water levels, requiring innovative solutions like resilient ship designs and climate-adaptive infrastructure. Through initiatives like the Maritime Masterplan, the Dutch government is investing in zero-emission technologies and sustainable shipbuilding to ensure IWT remains efficient and environmentally responsible. Collaboration between research institutions and industry stakeholders is driving practical innovations, strengthening IWT's role in European connectivity and global climate goals. The Netherlands is setting a benchmark for future-proof inland navigation by prioritising sustainability, resilience, and innovation.

KEY TAKEAWAYS

Climate resilience is crucial: The increasing frequency of extreme water levels due to climate change threatens IWT reliability, necessitating adaptive ship designs and infrastructure improvements.

Sustainability and innovation drive progress: Investments in zero-emission technologies, alternative fuels, and new vessel designs under initiatives such as the Maritime Masterplan can ensure a greener future for IWT.

Collaboration is key: Strong cooperation among the government, industry, and research institutions is essential for advancing climate-resilient, efficient, and sustainable IWT.

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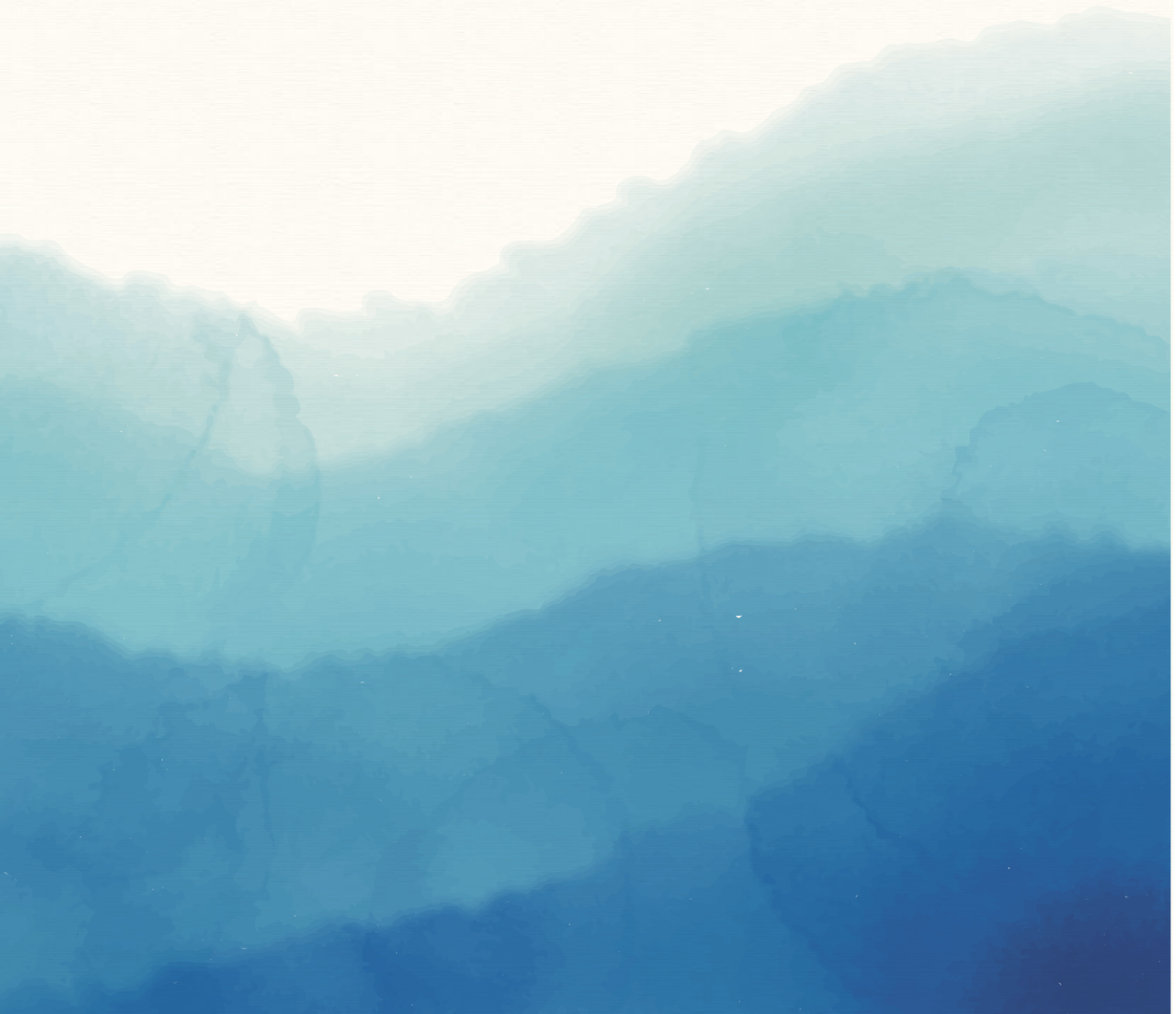
Section IV

Coasts and Communities: Maritime Governance and Social Impact

The Big Dhow: Decarbonising Shipping

Mohamed Nasheed



Industrialised and emerging powers have an interest in influencing trade routes. They require vast amounts of raw materials shipped to their production centres, where they add value by processing them, then sell the manufactured goods to whoever wants to buy them.

China's interest in the Indian Ocean has expanded with the Belt and Road Initiative (BRI), which comprises two key components: the Maritime Silk Road Initiative and the Silk Road Economic Belt (1). This large-scale geopolitical project aims to develop infrastructure facilitating trade and investment, promoting economic cooperation and connectivity across Asia, the Middle East, Africa, and Europe (2).

India has policies and investments to build similar networks to the East and West: the 'Act East' policy and the 'Sagarmala' project (3). These initiatives aim to enhance connectivity and economic integration with neighbouring countries and regions. The Act East policy seeks to strengthen economic and strategic relations with Southeast Asian countries (4). It focuses on trade, investment, infrastructure development, and cultural ties. The Sagarmala project promotes port-led development to improve maritime infrastructure (5).

India is also actively developing the International North-South Transport Corridor (INSTC), a multimodal transportation network that aims to enhance trade connectivity between India and Western countries, particularly Russia and those in Central Asia and Europe (6). The INSTC is a 7,200-km-long network of ship, rail, and road routes that facilitate freight movement between India, Iran, Afghanistan, Armenia, Azerbaijan, Russia, Central Asia, and Europe (7).

However, these mega trade route projects are often planned and built using fossil fuel technologies that date back to the Victorian era, with little adaptation to contemporary sustainable alternatives. The internal combustion engine, a relic of the past, is no longer viable for the future. As humankind transitions towards sustainable transport and renewable energy sources, it is evident that relying on these antiquated technologies will likely render projects uneconomical and lead to financial disasters (8). The global shift towards greener, more efficient alternatives highlights the need for modern infrastructure that aligns with the principles of sustainability and environmental responsibility.

For centuries, navigators, merchants, and shipowners in the Indian Ocean played a key role in maintaining and managing the trade routes that spanned its vast waters (9). Ports and harbours extended from the Arabian Gulf down to the Swahili Coast in the west, reaching as far east as Malacca. In the north, they connected Gujarat, the Malabar and Coromandel coasts, and the Bay of Bengal, while in the south, they linked the island nations. Trade and navigation cultivated deep connections between hundreds of ports and countless families, shaping relationships through commerce, marriage, and cultural exchange.

Portuguese rule significantly enhanced boat-building skills in the Indian Ocean port cities but also disrupted local trade networks, taking commerce away from Indigenous and local families. This was followed by the Dutch, the East India Company, and later the British Empire, which progressively took control of and colonised key port cities. Under British colonial rule, cargo operations were centralised in a few major ports. However, Britain's promotion of free trade allowed local traders to engage more openly in commerce across Indian Ocean states.

The strength of the Indian Ocean rim ports and their hinterlands comes from their relatively small size. Their traditional vessels, such as *dhows* and *dhonis*, adjusted in size based on trade demands (10). Skilled navigators expertly understood the region's winds, currents, reefs, and shallow waters, ensuring safe passage. Merchants maintained extensive trade networks and credit systems across Indian Ocean ports. Their political influence and ability to shape state policies remain unmatched, making them a uniquely powerful economic force.

Efforts to unify Indian Ocean trade routes under the BRI have yet to materialise fully. Several host countries for BRI ports are facing severe economic challenges, with some on the brink of bankruptcy or already in default. Take the case of Sri Lanka, which defaulted on its debt, while economic instability looms over East African port nations and Pakistan (11). The strategy of centralising trade in major hub ports has primarily resulted in underutilised infrastructure projects, often referred to as "white elephants," scattered across the Indian Ocean rim (12). Meanwhile, the financial burden of these non-performing developments continues to strain local economies and livelihoods (13).

While economies of scale and mega ports may seem beneficial, they often fall short compared to smaller, more adaptable units that generate inclusive and sustainable growth. Relying on debt restructuring to sustain large-scale infrastructure projects in Indian Ocean port cities is not a viable long-term solution. Instead, the future vision for Indian Ocean states should prioritise flexible, resilient, and locally driven economic models.

Indian Ocean states continue to honour their maritime heritage through various means, with numerous national and private shipping lines and a wide array of traded commodities. By utilising advanced ship designs and hybrid propulsion systems that integrate wind and fuel, maritime transport efficiency can be significantly enhanced. Revitalising regional trade networks will not only support struggling port city economies but also foster peace and stability throughout the Indian Ocean region.

Efforts to decarbonise the shipping industry through a maritime levy are ongoing in International Maritime Organization (IMO) negotiations (14). The Climate Vulnerable Forum and its finance ministers' group are assisting member countries in a fellowship to improve access to analytics (15). Shipping nations will likely agree to a maritime levy, but the allocation of the funds raised by such a levy remains undecided (16). The Loss and Damage Fund could take a portion of those funds (17), while the bulk should be spent within the industry to develop low-carbon propulsion. The efficiency of small *dhow* feeding mega ports can be enhanced, and the wind-powered very large crude carrier *dhow* can also be developed.

The largest wind-powered vessel currently under development is the Oceanbird (18), designed by the Swedish shipping company Wallenius Marine. With a length of 200 meters (656 feet), it is designed to transport up to 7,000 cars across the Atlantic at a speed of 10 knots (19). The Oceanbird aims to reduce carbon emissions by 90 percent compared to conventional ships powered by fossil fuels (20).

Another notable wind-powered vessel is the Neoliner Origin, a 136-meter (446 feet) long roll-on/roll-off cargo ship that can carry 5,300 tonnes or about 265 containers (21). It aims to cut carbon emissions by 80 percent (22).

In other words, the future of Indian Ocean shipping should not be an attempt to recreate the failed BRI model characterised by mega ports, mega debts,

and mega defaults. One must look to the past—with the many smaller ships and vibrant trade, benefiting more ports and families—and look to the future—with new technologies of the post-fossil fuel age—to build a thriving, prosperous, and peaceful Indian Ocean region.

KEY TAKEAWAYS

Sustainable trade infrastructure over mega projects: The BRI's large-scale ports have led to debt crises and underutilised infrastructure. Indian Ocean nations should instead focus on smaller, adaptable trade networks for sustainable growth.

Leveraging maritime heritage for resilience: Indian Ocean trade thrived on small ports and traditional boats like dhows and dhonis. Revitalising these with hybrid propulsion and efficient small-scale shipping can boost economic resilience, restore livelihoods, and enhance regional stability.

Decarbonising maritime trade for the future: The reliance on fossil fuel-based infrastructure is outdated and unsustainable. Wind-powered vessels such as the Oceanbird and Neoliner Origin, supported by an IMO maritime levy, can drive the shift to low-carbon propulsion systems.

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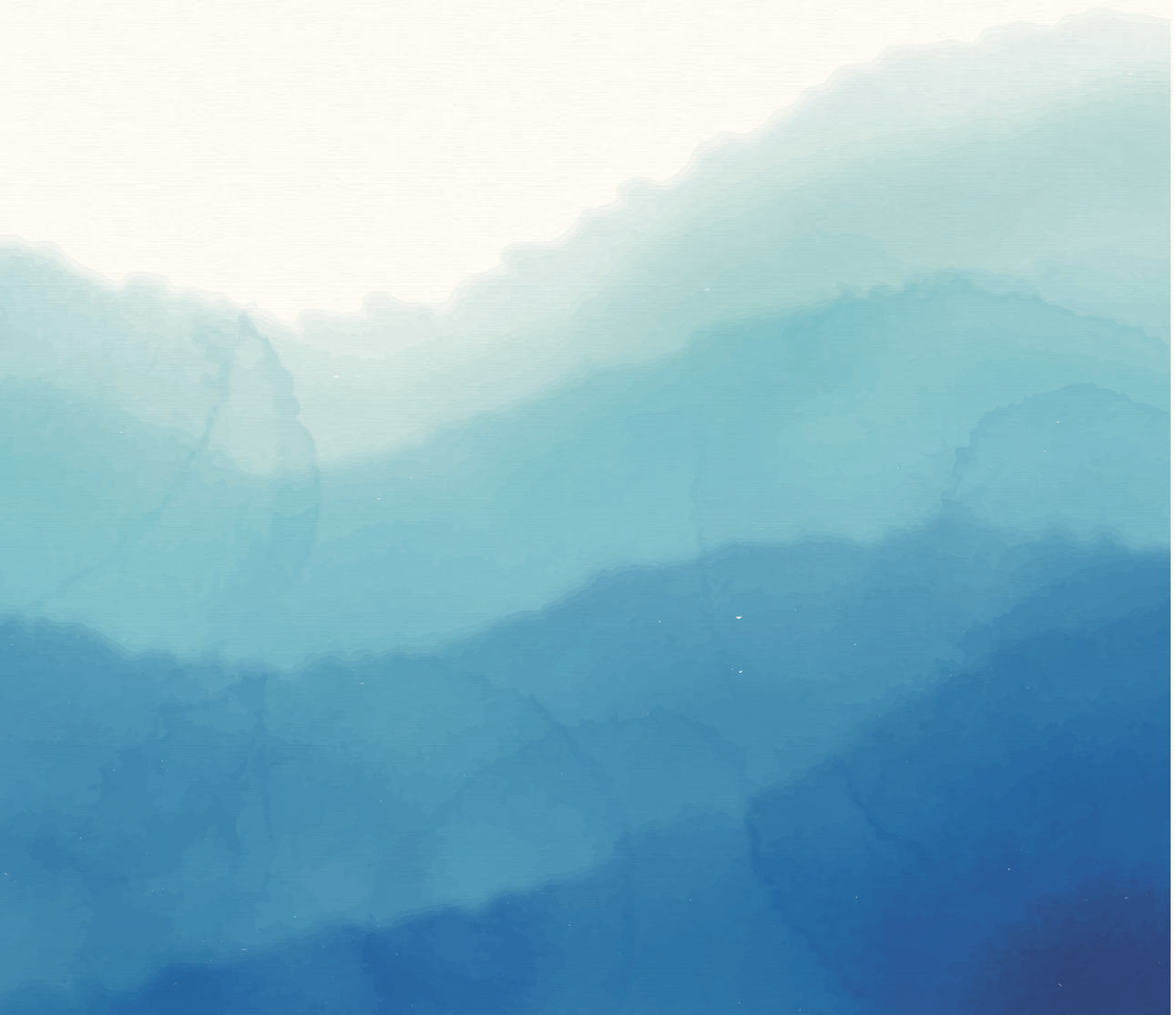
Shaping an Inclusive Blue Future: Maritime Governance and Coastal Communities

Malshini Senaratne



With 40 percent of the world's population living within 100 km of a coast, the significance of the ocean to their wellbeing and security is immediately apparent (1). Maritime spaces account for over 80 percent of the world's trade and house marine ecosystems that provide communities with food, minerals, and livelihoods (2). However, these spaces have become the centre of growing strategic competition, where national security and resource interests collide. Against this backdrop, the impacts of climate change—temperature changes, extreme weather events, and sea level rise—also disproportionally affect Small Island Developing States (SIDS) and their coastal communities (3). As existing global and regional frameworks, such as the United Nations' Convention on the Law of the Sea, the International Convention for the Prevention of Pollution from Ships, and the Paris Agreement, struggle to deal with these challenges, the need for a fresh approach to maritime governance has become increasingly evident (4). In response, several countries have integrated the blue economy model in their development pathways to consolidate a more people-centred governance approach (5).

Blue Economy and Climate Resilience

The World Bank defines the blue economy as "the sustainable use of ocean resources for economic growth, improved livelihoods, and job creation while preserving the health of ocean ecosystems." (6) The blue economy is made up of multiple sectors, including traditional (such as fisheries, tourism and shipping) and emerging sectors (including marine biotechnology, aquaculture, offshore renewable energy, and marine research and education) (7). With an annual economic value of at least US$2.5 trillion, the global blue economy would be the seventh-largest if it were a country (8). By promoting sustainable ocean development, the blue economy framework aims to enhance climate resilience in vulnerable countries, especially SIDS (9).

Seychelles launched its blue economy model in 2018 to sustainably develop its 1.3 million km of ocean. As part of the initiative, the country also issued the world's first sovereign Blue Bond, valued at US$15 million, to mobilise financial resources for local communities and businesses—funding often difficult for small island states to access (10). Seychelles designated 26 percent of its waters as a marine protection area (MPA), which increased the resilience of its fisheries and tourism sectors, provided safe havens for fish

species, and, most importantly, assisted the coastal communities that depend on the sea for their livelihoods (11). The state is now finalising a blue carbon policy (12), reinforcing its commitment to protect 50 percent of its seagrass and mangrove habitats in 2025 (13).

Maritime Livelihoods and Just Economic Transitions

Notwithstanding the impacts of climate change, the blue economy is a growing space; the global maritime industry alone is expected to grow from US$2,181.09 billion in 2024 to US$2,920.0 billion by 2035, and currently employs over 1.2 million people at sea (14). While this presents significant opportunities for many countries, the domain also faces major governance challenges due to its size and weak enforcement. These challenges range from battling organised crime, terrorism, piracy, human rights violations, and drug trafficking to illegal, unreported, and unregulated (IUU) fishing (15).

The sector also remains a male-dominated industry. In 2021, women accounted for only 2 percent of maritime sector workers (16). A lack of gender-inclusive policies has resulted in systemic barriers—including discriminatory hiring practices, exclusionary policies, and limited access to leadership roles—preventing women from fully participating in the industry (17).

The maritime sector is supported by coastal communities that sustain livelihoods and generate employment opportunities in the shipping, energy, and tourism industries (18). However, these communities are also the most vulnerable, putting their cultural and spiritual connection to the sea at risk. For many, the ocean is a sacred place, and water is much more than just a resource; it is revered as a universal life-source (19). Climate change-driven impacts (20) coupled with human-induced impacts such as overfishing and marine pollution (21) are drastically transforming the coastal landscape while simultaneously undermining the population's health, resilience, and customs (22). Moreover, artisanal fishers—who represent more than 90 percent of the workforce in developing countries—face persisting challenges, including poor working conditions, marginalisation in the participation of policy initiatives, and a disregard for their indigenous knowledge (23). In the Solomon Islands, for example, traditional customary marine tenure (CMT) defies the 'tragedy of commons' theory and demonstrates an alignment with modern blue economy principles of sustainable development. The community uses generational knowledge of the environment—including natural processes, spawning aggregates and species' growth rates—to make sustainable decisions about fishery management, reflecting a flexible system rooted in history with ties to the broader cultural and social system (24). However, formal recognition of systems such as CMT and indigenous rights are largely limited within current policy frameworks.

These issues have raised calls for a just transition, a concept associated with a move towards environmentally- and socially-sustainable economies while ensuring that all of society benefits (25). The blue economy provides a pathway to support this shift by reinforcing sustainable fisheries and ecosystem-based management, and the principles enshrined within the Sustainable Development Goals, among others.

Technological Innovation and Entrepreneurship in the Blue Economy

The intersection between entrepreneurship and technology in enabling sustainable resource management and scalable venture creation has become a key factor in the growth of the blue economy, especially for coastal communities.

Through artificial intelligence and advanced modelling systems, Tuvalu can now clearly identify and warn coastal communities of risks associated with sea level rise and storm surges (26). Ninety-eight percent of Costa Rica's domestic electricity requirement is met through renewable energy sources alone (a combination of wind, solar and hydropower), and the country exports the excess power generated to its neighbours (27).

Sustainable ventures that centre around the well-being of the community they operate in are also emerging. Seaweed Seychelles enlists volunteers, workers, and fishers to collect seaweed that accumulates on the shoreline by hand and transforms the product into liquid fertiliser (28). In Senegal, business interest in seaweed farming has increased through the provision of training courses for local communities and women on seaweed cultivation techniques (29). In this vein, dismantling gender barriers in the blue economy has also become a crucial business tool. In Bangladesh, coaching for women in the blue economy has increased negotiating skills and boosted assertiveness (30). These initiatives showcase how technological advancements and new blue ventures reinforce the blue economy's sustainable growth objectives alongside social equity.

Rethinking Governance

Despite the benefits of the blue economy, its growth will encounter challenges in current governance policies, institutions, and mindsets. These include maintaining an upward political momentum for the framework, ensuring meaningful stakeholder engagement, and inducing effective multi-sectoral coordination and institutional capacity (31). International organisations such as the United Nations and the International Maritime Organization, as well as regional ones such as the African Union and the Pacific Islands Forum, play a pivotal role in shaping policies and fostering cross-border cooperation. At the grassroots level, coastal communities are often the vanguard when it comes to the defence of marine ecosystems. They also possess far more knowledge about the sustainable resource management of such ecosystems than other stakeholders (32). Despite this, they are often marginalised or completely overlooked in decision-making processes (33). As a result, coastal populations experience vulnerability, even as the blue economy promises more prosperity. The struggle to bridge the divide between an ambitious global framework and the local reality for communities has led to concerns that "[…] the status quo does not meet the diverse development aspirations of coastal communities or ensure healthy oceans for current and future generations." (34)

To address these concerns, governments should prioritise capacity development and empowerment initiatives related to gender inclusivity, improved ocean and financial literacy, technological capacity, and entrepreneurship for these communities (35). India is attempting this shift through the Maritime India Vision 2030 and Maritime Amrit Kaal Vision 2047 by securing partnerships that will provide adaptable technology to the local setting, thus reducing the challenges faced by the country's coastal population (36).

Transformational policies that empower small-scale fishers will also assist the well-being of their communities and the overall health of the marine ecosystems and the global food supply chain. Brazil has established cooperatives for collective equipment purchases, training programmes for sustainable fishing practices, and public-private partnerships for direct-to-consumer sales and funding opportunities, which are helping empower its fishing communities (37). To drive true change, policymakers must also recognise coastal communities as essential stakeholders, and not just beneficiaries of policy outcomes.

Conclusion

The blue economy model remains far from perfect because the insistence on economic growth over the principles of environmental sustainability and equity means that the promised circular economy is not within easy reach (38). Addressing limitations within maritime law requires a rethink in adaptive maritime policies and a shift towards more flexible institutions if future challenges in maritime governance are to be anticipated. Otherwise, the growing influence of non-state actors in this space suggests worn-out governance mechanisms may be overturned or ignored in the blind willingness to pursue economic growth above all else.

High-level policy discussions around the blue economy continue to assume that benefits will trickle down to communities, but meaningful discussions around indigenous people, their knowledge, and their social equity are often an afterthought (39). The 2024 'Sagarmanthan Dialogue' hosted by India sought to reverse this trend by exploring ideas that could shape twenty-first-century global maritime policy from a people-centric approach (40). A sustainable blue economy offers direct benefits for coastal communities through alternative and sustainable livelihood generation, enhanced food security, and improved equity and governance rights (41). Therefore, putting communities at the centre of a clear governance framework will result in policymakers, the private sector, and people speaking a shared language to shape an equitable ocean economy underpinned by social justice (42).

KEY TAKEAWAYS

- The blue economy model offers opportunities to promote sustainable, people-centred governance while addressing complex maritime issues.
- Coastal communities are vital but vulnerable; a just transition emphasises the need to recognise communities as essential stakeholders and support their participation in governance.
- Governance frameworks should evolve to be more inclusive, prioritise local knowledge, and integrate policies that align economic needs with environmental and social sustainability.

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Building Resilient Coastal Communities: Governance, Climate Action, and Inclusive Growth

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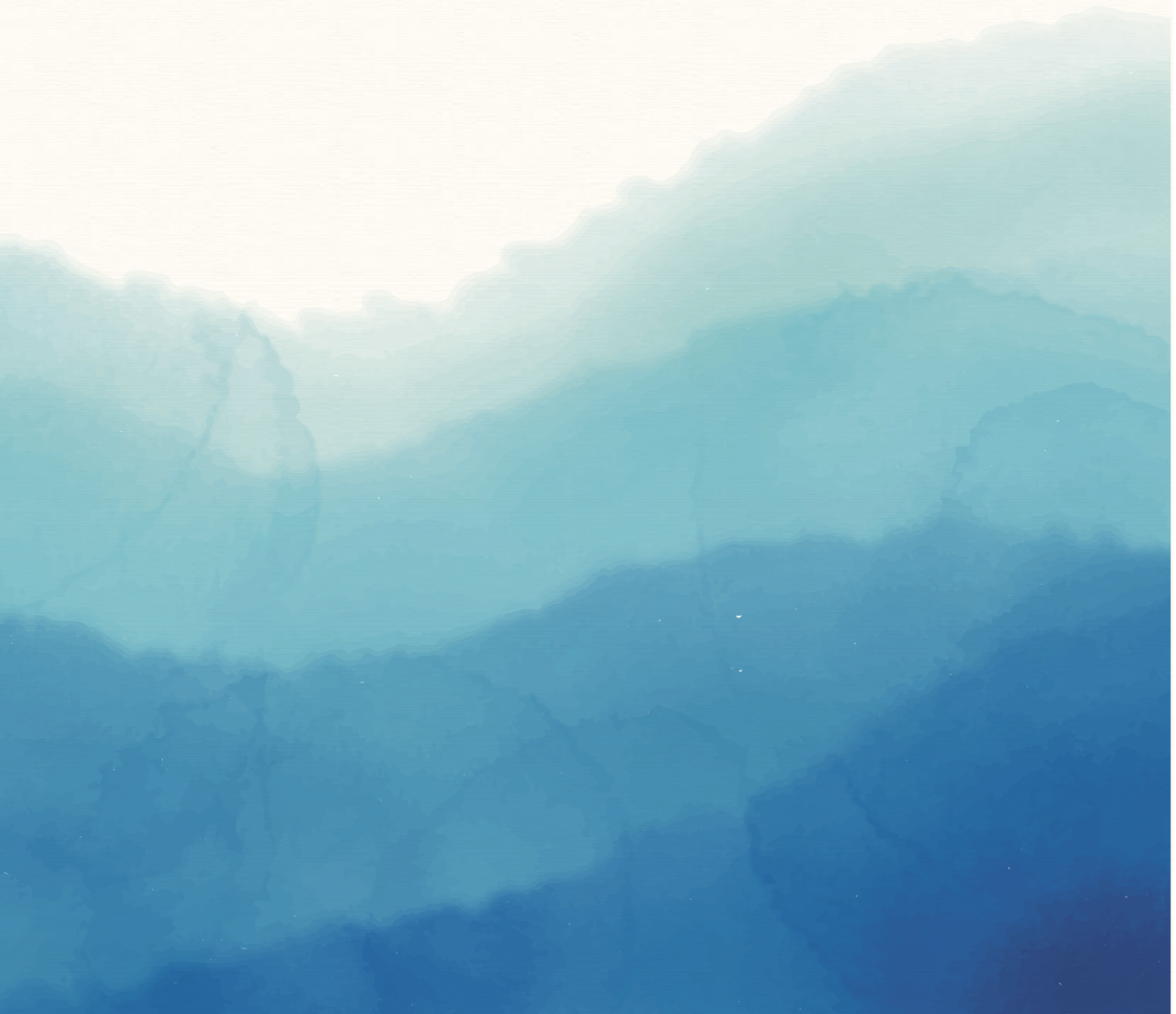

Coastal communities face escalating climate-induced risks, economic vulnerabilities, and governance challenges, highlighting the urgent need for maritime resilience and governance (1). This essay explores the intersection of climate adaptation, multihazard early warning systems, and sustainable blue economy frameworks (2). Home to 40 percent of the global population and 80 percent of trade, coastal zones are vital hubs but face mounting climate and governance pressures (3). India's coastline, now redefined as 11,098 km due to advances in geospatial mapping (4), underscores the need for updated risk assessments and adaptive resilience strategies. Home to over 250 million people (5), the region faces rising seas, extreme weather, and socioeconomic disparities that require mitigation.

Through insights from best-practice models, this study examines how multistakeholder governance, digital innovations, and nature-based solutions (NbS) (6) can enhance coastal resilience. It addresses a key question: how can policy-driven adaptation, community-led initiatives, and technology integration reduce coastal vulnerabilities? Sustainable coastal governance must integrate climate strategies, digital tools, and community empowerment to deliver adaptive and scalable solutions. By aligning with local governance models and the Four Pillars of Early Warnings for All (7)—a UN initiative to ensure that everyone on Earth is protected by lifesaving early warning systems by 2027—this research offers people-centred pathways to safeguard ocean-dependent communities.

Challenges and Pressures Facing Coastal Communities

Coastal communities face converging challenges threatening their stability (8) and deep-rooted cultural ties. Rising sea levels, cyclones, erosion, and marine pollution are degrading ecosystems and jeopardising biodiversity and public health. The loss of mangroves and coral reefs weakens natural coastal defences, while overfishing, ocean warming, and habitat degradation undermine food security and economic livelihoods, underscoring the need for sustainable resource management (9).

Rapid urbanisation, unregulated tourism, and unstable fisheries amplify socioeconomic vulnerabilities (10). Conservation efforts often conflict with the livelihood-based needs of fisherfolk and small enterprises. The underrepresentation of women, marginalised groups, and small-scale fishers in governance structures undermines inclusive decision-making (11). Inadequate sanitation and waste management exacerbate public health risks (12), especially in densely populated and underserved areas. In addition, subsidy reductions and stringent regulations have heightened (13) economic pressures, reinforcing the need for sustained financial support and adaptive capacity-building. Governance gaps—such as poor

coordination and digital infrastructure—hinder resilience (14). The enforcement of coastal zone management remains constrained by financial and institutional limitations (15). Furthermore, the disconnect (16) between ocean governance and climate policy, along with weak data and limited analytics, restricts sustainable coastal management and impedes climate-resilient decision-making.

Building Sustainable Futures for Coastal Communities

- **Leveraging technology**

Building resilient coastal communities requires investment in climate-resilient infrastructure, artificial intelligence (AI)-enabled early warning systems, and the integration of NbS into planning frameworks. Reliance Foundation's community-led model exemplifies this approach—engaging 23 percent of India's fisherfolk, achieving a 95 percent adoption rate of ocean forecasts, and contributing to a 15-23 percent increase in fisherfolk incomes (17). During the 2018 Kerala floods (18), its multisector partnerships enabled timely rescue operations, strengthening last-mile communication.

Digital tools reduce search time, improve safety, and support livelihoods. The M.S. Swaminathan Research Foundation's 'Fish for All' model (19) offers similar lessons— empowering marine fisherfolk, especially women, through sustainable practices and digital literacy. Locally-driven approaches (20) are more resilient than top-down models. Additionally, Geographic Information System platforms, Ocean Biodiversity Information System (21), and Flukebook (AI-driven cetacean research platform) (22) enhance marine monitoring.

- **Strengthening multistakeholder collaboration**

Collaborative models, such as the 'Mangroves for the Future' initiative in South and Southeast Asia, demonstrate how community-based resource management, backed by regional cooperation and private sector engagement, can strengthen coastal resilience and inclusive governance (23). Similarly, platforms like 'Sagarmanthan: The Great Oceans Dialogue' (24) further enable cross-sector collaboration and policy alignment with evolving climate commitments. Such models foster tech-enabled solutions for sustainable ocean governance.

- **Bridging science, policy, and practice**

Bridging science, policy, and practice requires AI-driven governance, community-led strategies, and evidence-based decision-making. AI-powered risk mapping can identify vulnerabilities, optimise evacuations, and strengthen early warnings. NbS—including mangrove bio-shields (25), tsunami-ready villages (26), and integrated coastal wetland management (27)—must be embedded within broader climate adaptation frameworks and aligned with UNESCO's conservation standards (28) to ensure long-term ecosystem resilience.

- **Empowering coastal communities through localised solutions**

Incorporating ocean health policies into gram panchayat development plans (GPDPs) (29) can further localise climate action. As decentralised planning tools under India's Panchayati Raj system, GPDPs enable communities to identify and prioritise coastal development needs tailored to socioecological contexts. Community resilience committees—comprising fisherfolk, women leaders (30) and youth representatives—can ensure inclusive governance and integration into national climate action plans. Trained local leaders help protect biodiversity, curb illegal fishing, and enhance disaster readiness.

Strengthening coastal livelihoods requires diversifying income opportunities through initiatives such as cage farming—raising fish in submerged enclosures—and seaweed cultivation—growing marine algae for various uses (31) Microfinance plays a crucial role in supporting small-scale fisherfolk in adopting sustainable practices, while coastal conservation funds for mangrove and wetland restoration can attract private sector investment in resilient infrastructure (32). Regional collaboration across South and Southeast Asia enhances knowledge sharing, enabling the development of tailored resilience solutions, region-specific governance strategies, and evidence-based policies. Such coordination is key to advancing long-term coastal resilience (33).

Conclusion

Sustainable ocean governance aligns the blue economy with data-driven decisions, scaling NbS and cross-border policy-science links. This approach safeguards ecosystems and supports coastal sustainability.

KEY TAKEAWAYS

Integrated technology and nature-based governance: Embedding AI, real-time tools, and NbS into local governance frameworks, such as GPDPs, enhances early warnings, adaptation, and risk reduction. Systems like the Indian National Centre for Ocean Information Services' Ocean Forecast (34) enable real-time risk assessments and data-informed decision-making.

Inclusive, community-led resilience building: Empowering fisherfolk, youth, and indigenous leaders through inclusive governance and ocean literacy fosters long-term resilience.

Policy coherence and sustainable blue economy: Aligning resilience with SDG-13 (climate)/SDG-14 (life below water) and public-private partnerships supports policy coherence and sustainable blue growth.

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Coastal Communities and Ocean Governance: A Quest for Meaningful Public Participation

Vishal Surbun

Approximately 40 percent of the world's population lives within 100 km of the coast, and human settlements are generally more concentrated in coastal zones than elsewhere (1). According to UN indicators of sustainable development, this concentration is attributed to economic benefits from access to navigation and seaports, coastal fisheries, tourism, and recreation (2). However, alongside migration to coastal urban areas, extant indigenous coastal communities (CCs) may have a deep, generations-long connection to the ocean as an environmental, economic, cultural, and spiritual domain. This deep connection crystallises in the development of indigenous and traditional knowledge systems, which can transcend Western legal notions of rights. These systems also reflect holistic ways of thinking based on intimate relations between humans and other species (3). It has been contended that "these aspects of co-existing with the marine environment are essential for halting extractive or overly exploitive approaches to ocean governance" (4).

CCs' interaction with the ocean for cultural and subsistence needs has often come into friction with the interests of other stakeholders (5), including national regulatory bodies, port authorities, and ocean-based industries such as tourism operators, energy companies and commercial fisheries. As these industries provide resources for human nutrition, health, and economic development, fostering their growth is becoming an increasingly key focus in national policies (6).

However, with large-scale attention and investment in these industries, CCs are left marginalised, and their use of the ocean for cultural and subsistence needs faces challenges of reduced access to resources and limited public participation in decision-making. In Africa, CCs still deal with the lingering effects of their colonial histories (7), which included their forced removal and displacement (8) to make way for infrastructure development arising from tourism and port expansions, for example, permanently altering their ancestral land and seascape and disrupting sensitive ecosystems.

CCs' participation in decision-making is therefore critical because (i) they often possess a deep symbiotic relationship with their ancestral coastal land, and have developed long-established indigenous knowledge systems, and (ii) it promotes social equity, thereby redressing to some extent colonial legacies. Public participation is a core element of environmental impact assessments (EIAs) that emerged internationally after the 1972 Stockholm Conference (9) as an accepted norm in environmental decision-making (10). The United Nations Convention on the Law of the Sea (11) provides for EIAs but lacks a provision for public participation. However, other regional environmental treaties have addressed the concept of public participation, particularly the 1998 Aarhus Convention (12) and the 2018 Escazú Agreement (13). Sustainable Development Goal 16 ('peace, justice and strong institutions') contains two targets providing for public participation: target 16.7 is to "ensure responsive, inclusive, participatory and representative decision-making at all levels", and target 16.10 is to "ensure public access to information and protect fundamental freedoms in accordance with national legislation and international agreements" (14).

Using these treaties, scholars developed 10 evaluation criteria for best practices in public participation (15). These are: a broadly representative sample of participants; proactive, early, and full engagement with the public; a process conducted in an independent, unbiased way; a transparent process; a process for participation in a way that is clearly structured and explained; where the nature and scope of participation are well defined; where participants have access to the appropriate resources to participate under equal conditions; where the public is informed of how their views influenced decisions; where the procedure is cost-effective in proportion to the scale of possible impacts; and provision of environmental information used in decision-making (16). These criteria show that the participation of CCs is integral to coastal marine environmental decision-making that affects them (17).

Notwithstanding these criteria, there can be shortcomings and flaws in the process of CCs' participation in decision-making. These flaws were illustrated in the recent domestic litigation involving CCs in the Wild Coast region of South Africa (18). In this case, major oil companies intended to conduct a seismic survey along the Wild Coast region pursuant to an exploration right granted by the government in accordance with prevailing legislation. The CCs approached the court for an interdict to halt the survey. They argued *inter alia* that the survey would introduce artificial noises into the ocean, causing disruption and disrespect to the spirits of their ancestors who reside in the ocean. A key argument of the CCs is that the decision to grant the exploration right was procedurally flawed because it failed to consult with interested and affected parties adequately (19). The oil companies claimed that all regulatory requirements regarding consultation had been met (20), and the CCs' challenge was brought based on specific customary law that was intentionally kept esoteric or hidden from outsiders (21). However, the court disagreed with the measures the oil companies took

to facilitate public participation and consultation, finding, for example, that the notices were in languages the communities could barely understand (22). The court held that: “meaningful consultations consist not in the mere ticking of a checklist, but in engaging in genuine, bona fide substantive two-way process aimed at achieving, as far as possible, consensus” (23).

In Kenya, CCs approached the High Court regarding the design and implementation of a port infrastructure project, which they argued was contrary to the country’s constitution and statutory law (24). The court, in considering whether there was sufficient participation of the CCs, noted that a key concept that it could not ignore is “environmental democracy, a term that reflects increasing recognition that environmental issues must be addressed by all, or at least a majority of those affected by their outcome, not just by the minority comprising the governments and leading private-sector actors” (25).

Conclusion

The meaningful public participation of CCs in decision-making is of critical importance. Despite an extensive suite of legislation and treaties concerning processes for public participation, the contentious cases brought before domestic courts, such as in South Africa and Kenya, reveal flaws in the process. Although the courts found in favour of the CCs, these procedural flaws could emerge in future actions of stakeholders, affecting CCs’ interests. Therefore, domestic legislative reform is required.

KEY TAKEAWAYS

- The input of CCs in decision-making can help identify and address issues at an early stage, thereby saving scarce financial and government resources in developing states.
- A tick-box approach to consultation by stakeholders seeking to engage in development and mining activities in the coastal zone is inadequate. It deviates from the best practices for public participation drawn from international treaties.
- National governments should assist CCs in documenting their maritime cultural heritage and indigenous knowledge systems by creating national registers of indigenous knowledge.

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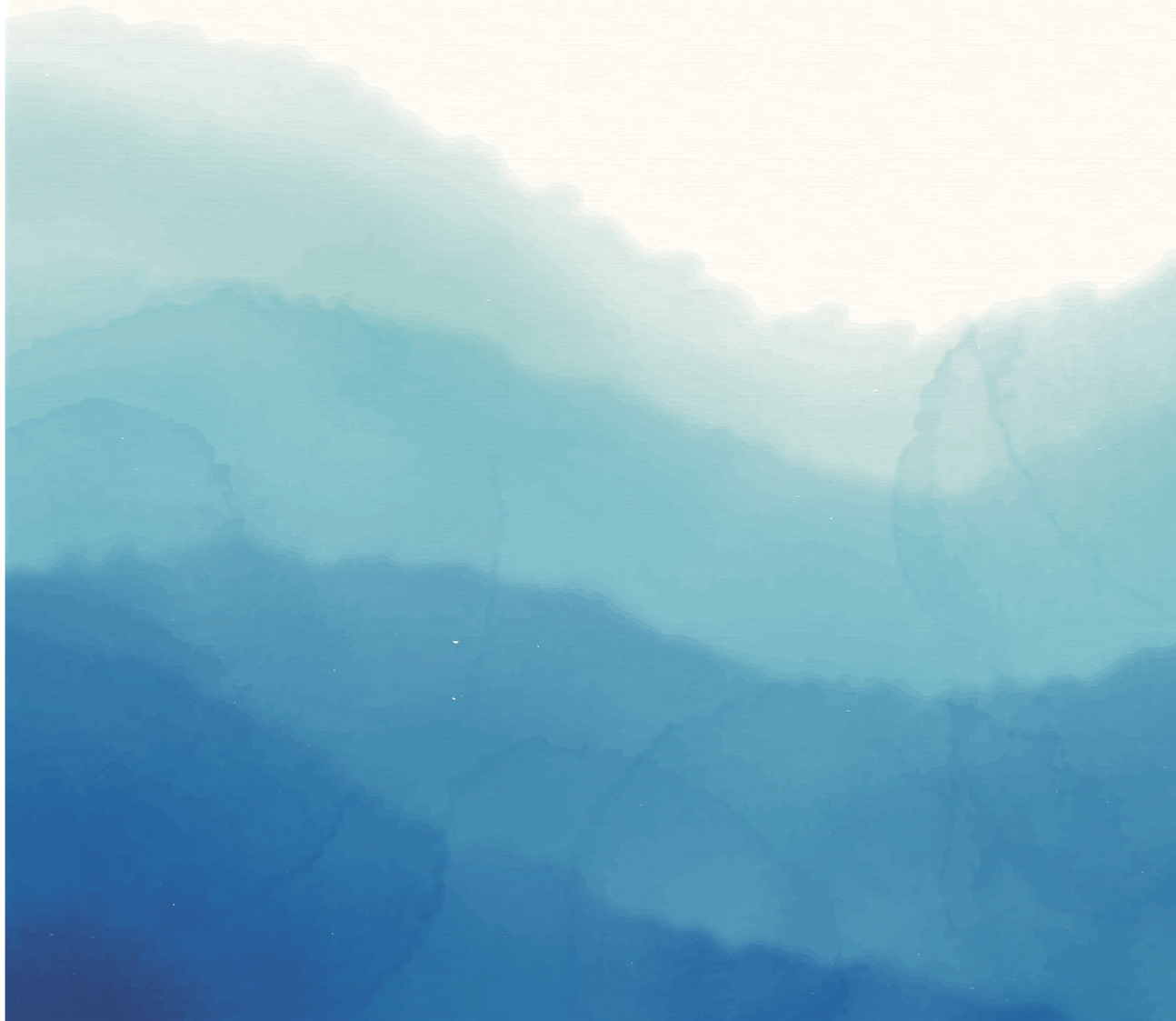
Sustainable Port Development: Balancing Economic Growth and Social Responsibility

Ishita Sharma



Sustainability is concerned with protecting the Earth by preserving and enhancing natural ecosystems (1,2). The United Nations' 2030 Agenda describes sustainability as maintaining well-being through a balance of prosperity, environmental protection, and social equity while safeguarding ecological systems, values, and natural resources (3). Protecting the natural environment and resources is fundamental to human existence and development, making it a cornerstone of sustainability (4). Human activities are integral to conserving natural resources and biodiversity as they directly influence environmental changes and biodiversity loss (5,6). This principle extends to the maritime sector, where ports act as vital gateways between sea and land, significantly influencing urban systems and local sustainability profiles (7, 8). In response, environmental considerations have been embedded in port legislation, leading to stricter standards in planning and operations. Research has also focused on sustainable operational strategies and green port management (9), with ongoing efforts continuing to shape environmentally responsible port policies and practices.

Port development drives maritime industry growth and economic expansion, and has significant environmental consequences (10). Studies highlight how strategic planning, innovation adoption (such as onshore power supply and alternative fuels), and operational activities contribute to pollution, ecological damage, and climate change risks (11).

In harbour and port operations, stakeholder engagement—including public and private sector actors—has encouraged the integration of sustainability into business strategy, operations, and reporting, often influenced by environmental non-government organisations (12). The industry is already addressing several port-related issues, such as energy efficiency, air quality, emissions reductions, resource conservation, and waste management (13), through initiatives under labels such as sustainable ports, eco-ports, and green ports (14, 15). Ultimately, the goal is to advance sustainability by implementing appropriate planning, which is considered a key step in port development. However, existing literature has yet to comprehensively explore sustainability-oriented planning approaches and their implementation and effects on ports (16). This presents an opportunity to further examine the planning dynamics of sustainable strategies within the framework of sustainable ports, eco-ports, and green ports.

Impact of Green Harbours and Port Development

Ports are integral to regional and global trade, contributing significantly to economic development. The rapid growth of trade has encouraged significant capital investment in port infrastructure, but has also contributed to environmental degradation, including water and air pollution, habitat loss, and increased carbon emissions. These impacts pose serious challenges for surrounding communities and ecosystems, necessitating sustainable solutions. Additionally, ports face rising operational costs, resource consumption pressures, and concerns over the quality of life in nearby urban areas. Although port development is often guided by regulatory frameworks (for example, many US seaports have integrated green port elements into planning, development, and operations to address environmental concerns, including resource consumption, rising costs, and quality-of-life impacts), these challenges highlight the need for more comprehensive and proactive approaches to sustainability.

Ports and shipping are major greenhouse gas emitters, with tankers, container ships, bulk ships, and trucks identified as key contributors. To mitigate these impacts, the green ports concept promotes eco-friendly practices, resource efficiency, and pollution reduction. The initial International Maritime Organization strategy targets a 40 percent cut in international shipping emissions by 2030 and a 70 percent reduction by 2050 from 2008 levels (17). Sustainable port development prioritises ecological concerns, monitoring environmental impacts, and adopting green initiatives that significantly impact environmental performance (18).

Sustainable port development is crucial for government agencies, port authorities, and terminal operators. The concept emerged in the twentieth century as the first environmental crisis demonstrated the limitations of unchecked economic growth. This led to the integration of the Sustainable Development Goals and mandatory green initiatives in port operations. Sustainable port development faces challenges in complying with environmental laws and mitigating risks. Key activities like port design, infrastructure planning, business models, investments, and corporate social responsibility initiatives seek to address these challenges while balancing economic, ecological, and social objectives. Many ports are now integrating sustainability into their vision and mission for long-term growth.

Ports achieve sustainability through effective planning and operations that minimise environmental harm while promoting economic, social, and environmental progress. Stakeholders have developed frameworks crucial to port sustainability, including linking supply chain and port stakeholders through strategic management and socially responsible marketing (19). A growing consensus emphasises shifting economic and social structures toward sustainable models (20). Additionally, port development can negatively affect ecosystems, leading to social and health impacts. Integrating ecosystem protection into port planning not only reduces harm but can also enhance port competitiveness. One study ranked ports using the analytic hierarchy process method, which breaks down complex problems into a hierarchy of more manageable sub-problems, with stakeholders then comparing these elements to establish priorities and make informed decisions, essentially verifying data consistency through sensitivity analysis. Similarly, another study developed a Port Sustainability Synthetic Index to assess the relationship between economic performance and environmental responsibility (21).

Conclusion

Globalisation has encouraged green development in ports for sustainability. Through a review of existing literature, this essay highlights sustainability approaches that reduce environmental damage. Green port development prioritises environmental concerns, minimising negative impacts while meeting future demands. Adopting green practices has become an effective strategy for sustainable port growth in the maritime industry.

Port operations have rapidly expanded in recent years, alongside growing concerns about climate change and rising energy consumption in maritime shipping. As a result, port industries face increasing pressure to comply with environmental regulations, particularly in areas such as vessel and cargo handling, port expansion, and hinterland connectivity. At the same time, ensuring adequate capacity, service quality, and cost-effective solutions remains essential for sustainable port development. Adopting green practices helps ports balance economic growth with environmental sustainability, supporting the transition toward a low-carbon maritime sector.

Green project planning addresses key decision-making challenges as ports seek to adopt energy-saving and emission-reduction strategies in increasingly competitive markets. CO_2 emissions, high construction costs, and excessive energy use are among the primary environmental concerns. These challenges underscore the urgent need for sustainable port development. Implementing green practices allows port industries to significantly reduce CO_2 emissions, lower construction costs, and minimise energy consumption, promoting environmental responsibility and economic efficiency.

Effective green practices also encourage climate-friendly infrastructure design, management, and operations strategies. These include stakeholder engagement, green market development, adopting cost-effective environmental policies, and integrating sustainability into daily operations. Such practices, managed by port authorities, are essential for embedding environmental considerations into the core structure and function of port systems.

KEY TAKEAWAYS

- Sustainable port development balances economic growth with environmental and social responsibilities.
- Integrating green practices, such as alternative fuels, energy efficiency, and emissions reduction, enhances environmental performance and long-term resilience.
- Strategic planning, stakeholder collaboration, and compliance with evolving regulations are essential for success.

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Towards an Inclusive Blue Economy: Indigenous Knowledge and Community-Led Pathways

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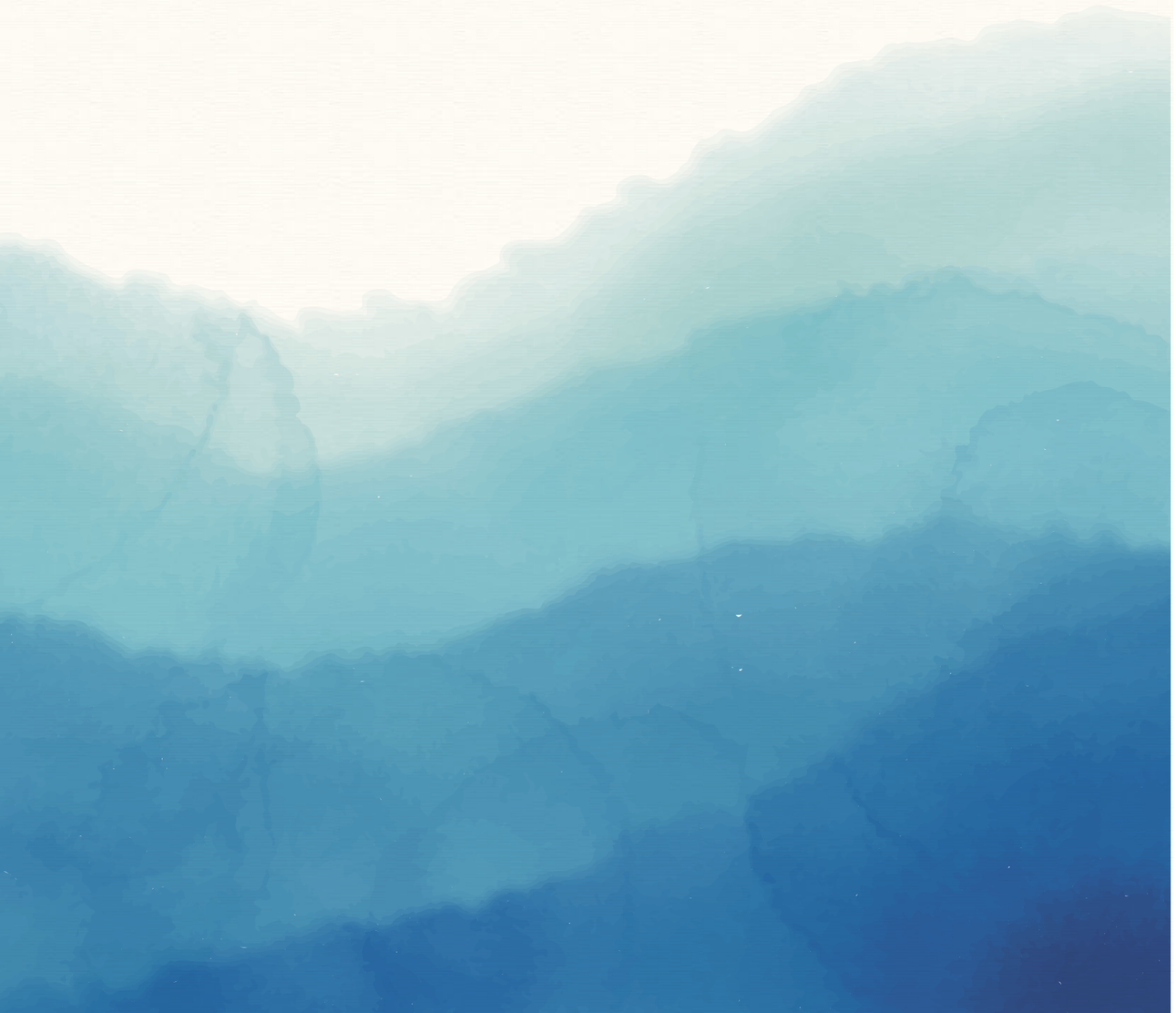

The 2023 Biodiversity Beyond National Jurisdiction Agreement marked a milestone in ocean governance (1). As a legally binding global treaty under the United Nations Convention on the Law of the Sea (UNCLOS), it advances marine conservation while recognising traditional knowledge, capacity building, and equitable benefit-sharing. Although its effective implementation is still taking shape (2), it signals the growing role of indigenous peoples and local communities (IPLCs) as key ocean stewards.

The increasing emphasis on the blue economy, defined by the World Bank as "the sustainable use of ocean resources for economic growth, livelihoods, and ecosystem health" (3), spans sectors such as tourism, aquaculture, marine biotechnology, ocean energy, and seabed mining. However, many initiatives prioritise economic and technological gains over social equity, often sidelining the rights, knowledge, and cultural ties of IPLCs.

These challenges are exacerbated by climate change, ecological degradation, and exclusionary practices such as "blue grabbing" (4) and top-down conservation (5).

Drawing on global case studies, this essay examines existing ocean governance frameworks, identifies key gaps, and proposes a policy pathway toward an inclusive blue economy that centres ecological integrity, social resilience, cultural heritage, and equitable access for IPLCs.

Existing Frameworks and Challenges to Inclusion

Existing frameworks focus on sustainable marine resource use, biodiversity conservation, and integrated coastal management, aligning with global sustainability goals while affirming the rights of small-scale fishers and IPLCs. As discussed below, several key instruments—both legal and voluntary, at global and regional levels—promote participatory, rights-based approaches and the inclusion of indigenous knowledge. However, implementation remains uneven and context specific.

Beyond UNCLOS, the Convention on Biological Diversity and the Kunming-Montreal Global Biodiversity Framework (2022) support Indigenous participation, yet IPLCs often face exclusion from decision-making and limited recognition of rights (6). The UNEP Regional Seas Programme promotes ecosystem-based

and indigenous knowledge approaches, but the impact varies (7). For example, conventions like Cartagena and Barcelona are active, but others face funding and policy challenges.

Voluntary frameworks, such as goal 14 of the Sustainable Development Goals (SDGs), support ocean conservation and small-scale fishers but lack mechanisms to integrate Indigenous knowledge (8). UNESCO's Local and Indigenous Knowledge Systems initiative and FAO's Small-Scale Fisheries framework highlight Indigenous inclusion, yet both remain non-binding and rely on national commitment (9). Regionally, strategies such as the Arctic Marine Strategic Plan, the African Union's Blue Economy Strategy, and the 2050 Blue Pacific Strategy integrate indigenous participation, but resource constraints often hinder effective implementation (10). Initiatives like the Coral Triangle and the Partnerships in Environmental Management for the Seas of East Asia encourage multistakeholder engagement but fall short on formal indigenous integration, while the Bay of Bengal Large Marine Ecosystem struggles with inclusive governance due to complex stakeholder dynamics (11).

Coastal management is also constrained by institutional fragmentation, limited funding, and development pressures—particularly in the Global South, where systemic and sociopolitical challenges persist alongside a disconnect between global goals and local realities (12). Generational shifts further contribute to the erosion of indigenous knowledge. At the national level, India's Coastal Regulation Zone notifications and the Draft National Fisheries Policy are important steps toward protecting coastal areas and recognising small-scale fishers. However, their impact must be strengthened through more explicit integration mechanisms and safeguards for IPLCs (13).

Despite efforts to promote participatory approaches, capacity gaps, data incompatibility, weak political will, and structural barriers—such as neoliberal models, post-colonial legacies, and centralised governance—continue to marginalise local voices (14). Bridging these gaps is crucial for a just and inclusive blue economy.

Successful Integration Models

The most effective blue economy initiatives recognise traditional rights, actively involve IPLCs, and equitably blend traditional and scientific knowledge. These approaches support fair benefit-sharing and adaptive governance, creating resilient, community-based models for just ocean management.

Countries like New Zealand and Canada have institutionalised indigenous co-governance in marine management. New Zealand integrates *mātauranga Māori* into fisheries management, while Canadian First Nations blend oral histories with satellite data via the Canadian Integrated Ocean Observing System to co-develop marine plans (15). In Scandinavia, Sámi communities are involved in marine planning (16), while Australia has implemented indigenous-led innovation in culturally grounded aquaculture and renewable energy (17). Inclusive blue economy models also support the SDGs, particularly SDG-2 (zero hunger) through sustainable fisheries and SDG-8 (decent work) via coastal tourism. Canada's Blue Future Pathways initiative connects youth to marine careers, promoting equity and empowerment (18).

In the Global South, community-based resource management integrates customary practices into governance. In Fiji and Madagascar, locally managed marine areas combine traditional systems with conservation science, boosting fish stocks and leadership (19). Chile's Territorial Use Rights in Fisheries (TURFs) and The Gambia's TRY Oyster Women's Association show how aligning equity with sustainability can restore ecosystems and enhance women's incomes (20). The Samoa Pathway further illustrates how culture and heritage drive resilience and climate adaptation in Small Island Developing States (21).

Integrated coastal zone management (22) and marine spatial planning offer tools to balance development and conservation, while enabling indigenous inclusion. Marine protected areas (23) are more effective when IPLCs participate, achieving ecological and cultural outcomes. In the coastal city of Kochi, India, traditional fishers' weather knowledge informs urban planning through multistakeholder partnerships, while unions like Matsyafed incorporate traditional practices into fisheries management, exemplified by the Marine Stewardship Council-certified Ashtamudi fishery (24).

Mumbai's Koli fishing community possesses deep ecological knowledge, viewing the sea as sacred and home to their deities—an outlook with significant potential for sustainable ocean management (25). Relying on seasonal marine movements and intertidal flows for generations, they are natural stewards of wetlands and mangroves vital for marine breeding and flood protection. When combined with GPS, their traditional understanding of weather and wind patterns can enhance early disaster warning systems. In Versova Koliwada, innovations like repurposing gillnets to filter plastic waste highlight their role in tackling coastal pollution (26). Harnessing this

knowledge can support their livelihoods, which are currently under pressure from industrial fishing, pollution, and rapid urbanisation.

However, these initiatives often face funding gaps, bureaucratic resistance, and political risks that hinder full implementation. While people-centred models yield significant local benefits, scaling them to influence national or regional ocean policy can be difficult due to institutional barriers, community hierarchies, regional disparities, and competing development priorities (27). This underscores the need to translate local successes into broader governance frameworks.

Pathway to Integration

Realising the full potential of the blue economy requires inclusive, community-led approaches that honour the ocean as a shared, living commons, with indigenous and local knowledge (ILK) at the core of decision-making (28). Despite growing recognition, ILK remains overshadowed by dominant scientific paradigms, limiting its contribution (29). When meaningfully integrated, it strengthens governance and supports more equitable, lasting outcomes. A people-centred approach that balances social, environmental, and economic goals is essential—demanding that global conventions move beyond technocratic fixes.

Emerging alternatives rooted in ILK worldviews can offer powerful counter-narratives, reimagining well-being and stewardship through relational, place-based approaches. These perspectives view the ocean as a collective resource, distinct from top-down master plans, emphasising care, reciprocity, and interconnectedness. Approaches like 'degrowth' challenge extractive models, prioritising sufficiency, while 'bottom-up sustainability' centres community-led solutions (30). Ecological Swaraj advocates decentralised self-rule in harmony with nature, and Buen Vivir envisions well-being as a balance between humans, nature, and community for ecological justice (31).

The proposed framework for an inclusive blue economy (see Figure 1) outlines five interrelated strategies, focusing on building trust and transparency among all stakeholders.

Figure 1: Proposed Framework for an Inclusive Blue Economy

Source: *Authors' own*

- **Legal and Policy Reforms**: Securing indigenous and community tenure requires embedding their rights in marine planning and sectoral policies. Key mechanisms include free, prior, and informed consent (FPIC) (32) that allows IPLCs to decide on activities affecting their resources and livelihoods, co-management models like Chile's TURFs, and legal frameworks such as Australia's native title laws (33). Legislative reforms are vital to align marine governance with indigenous laws and knowledge, ensuring equity and livelihood security.

- **Participatory Governance**: Promoting meaningful community participation requires polycentric governance and active civil society engagement. In India, the International Collective in Support of Fishworkers connects fisherfolk to policy platforms, while Australia's Great Barrier Reef Marine Park shows evolving polycentric governance, despite critiques on sidelining indigenous knowledge (34). Mainstreaming equity metrics and timely social impact monitoring is key, especially in developing contexts.

- **Knowledge Co-Production**: Bridging indigenous and scientific knowledge is vital to inclusive ocean governance. Community-led tools like participatory Geographic Information System (35) and the Fisher Friend App help

document traditional knowledge, now central to climate resilience and nature-based solutions. Ocean literacy must reflect indigenous and cultural perspectives to embed this knowledge in policy (36). Platforms like the Ocean & Climate Platform at UNFCCC COP29, Ocean Decade, and Sagarmanthan: The Great Oceans Dialogue create space for meaningful dialogue between indigenous communities and global leaders (37).

- **Equitable Economic Models**: Supporting community-led enterprises—like ecotourism, artisanal fishing, and mangrove stewardship—can align traditional practices with sustainable development. In emerging port cities of the Global South, blended finance models are key to balancing growth and ecological risk. Initiatives like the Mangroves for the Future programme in Asia-Pacific, which integrate social impact, demonstrate how innovative finance can attract private investment while promoting inclusive outcomes (38).

- **Capacity Building and Innovation**: Strengthening local governance through training, technology sharing, and peer learning is key to an inclusive blue economy. Initiatives like UNDP's Blue Futures and the Alaska Native Tribal Health Consortium empower communities in research and monitoring, while Tanzania's Marine Parks Unit (39) fosters cross-sector collaboration to integrate ILK. Investing in education and indigenous-led exchanges builds local capacity and ensures lasting community participation.

The proposed framework offers a pathway grounded in the strengths and lived realities of IPLCs, but its success hinges on collective action. Governments must embed indigenous rights and knowledge into marine governance through co-management, legal reforms, and tenure recognition. Community-led efforts like locally managed marine areas need funding and sociocultural impact assessments. International bodies should promote equity via ethical knowledge use and impact metrics, while the private sector must uphold FPIC and ensure fair benefit-sharing. While civil society can help connect communities to policy spaces, IPLCs must assert their rights through mapping and legal advocacy. Strong monitoring, evaluation, and reporting mechanisms will ensure that inclusive blue economy initiatives effectively deliver on their promises.

Conclusion

The blue economy offers a unique opportunity to align sustainability with inclusive development and human well-being. Centring local communities and indigenous knowledge fosters resilience and justice. The proposed integrated framework provides a pathway towards inclusion, but realising this vision will require scaling proven models through global, multistakeholder collaboration to achieve sustainability and equity.

KEY TAKEAWAYS

A sustainable blue economy must prioritise local communities, social equity, and indigenous knowledge, not just technical fixes.

The proposed integrated model for inclusive blue economy comprises five key strategies: legal reforms, participatory governance, knowledge co-production, equitable economic models, and capacity building.

Realising the vision of an inclusive blue economy requires scaling proven models through regional, national, and global multistakeholder collaborations.

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