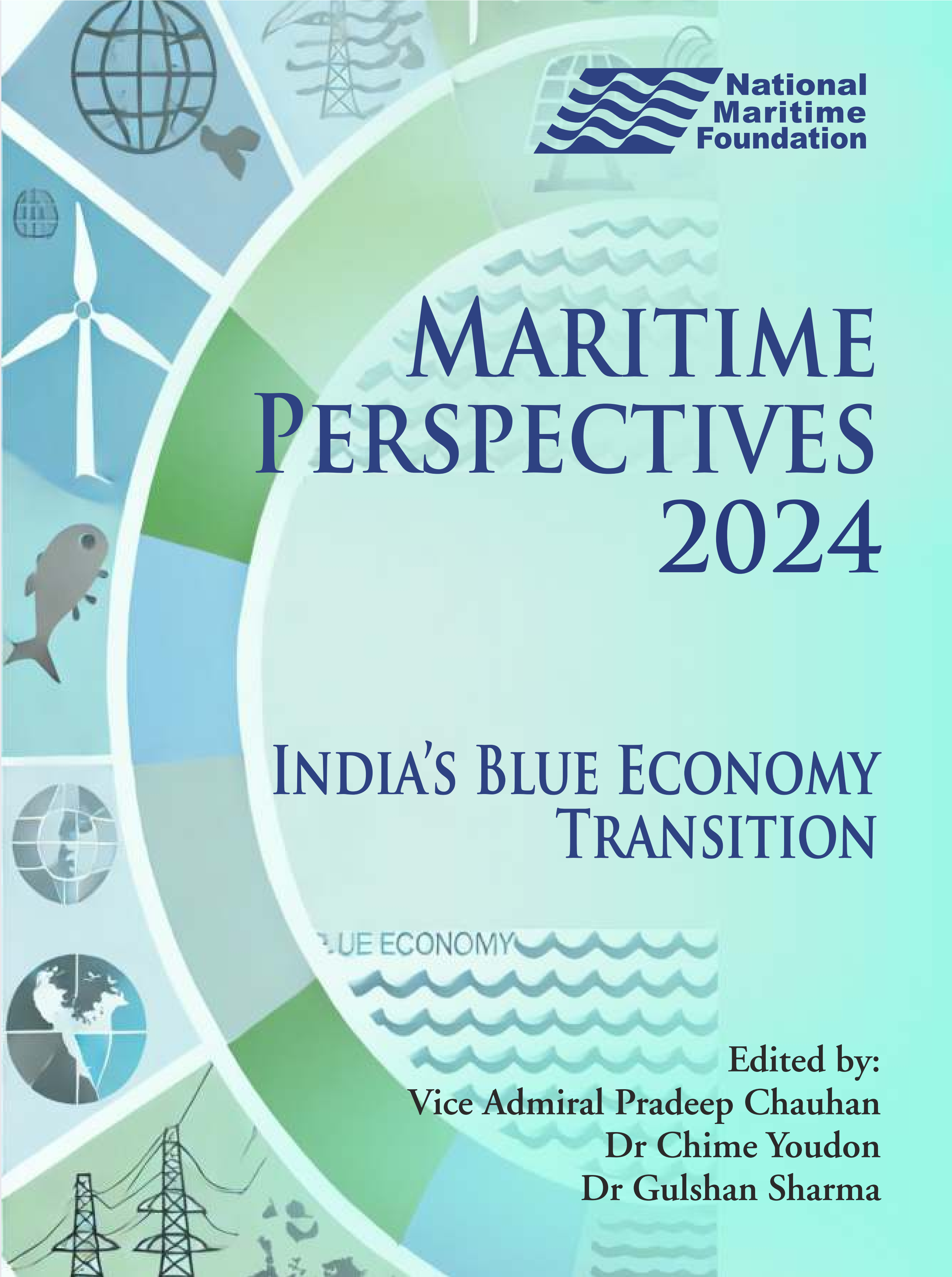

National Maritime Foundation

MARITIME PERSPECTIVES 2024

INDIA'S BLUE ECONOMY TRANSITION

Edited by:
Vice Admiral Pradeep Chauhan
Dr Chime Youdon
Dr Gulshan Sharma

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VOLUME IV: INDIA'S BLUE ECONOMY TRANSITION

Editors: Vice Admiral Pradeep Chauhan, Dr Chime Youdon and Dr Gulshan Sharma

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Foreword

India's mental map of the regional maritime landscape of the Indo-Pacific is undergoing a transformational shift as the country's endeavour to transition from its existing "brown" model of economic development to a "blue" one gathers momentum, catalysed by the immediacy of adverse impacts of climate change. The very ambit of our endeavour itself is rapidly shifting from one driven by purely national considerations to one that reflects an increasing awareness that India, needs to take the lead in preserving and protecting the maritime common by developing a collective and inclusive move to a sustainable, regional blue economy. This attitudinal shift is especially noticeable in the western segment of the Indo-Pacific, namely, the Indian Ocean. Here, India is expected to be an exemplar, and it, too, seeks to be one.

However, this transition to a "blue" economy is a complex one and encompasses multiple facets. With a coastline in excess of 11,084 kilometres, India is uniquely positioned to leverage its marine resources while safeguarding its delicate ecosystems. Precisely because of this impressive length of coastline, the deep relationship between a blue economy and sagacious management of the coastal environment has developed into a major focal point of the Indian transformation. The urgency being evidenced in India's search for clean energy transitions for shipping underscores India's commitment to reducing its carbon footprint and achieving net-zero emissions by 2070. The integration of renewable energy sources within the maritime sector is not merely a goal; it is an imperative for sustainable growth. Likewise, sustainable tourism, too, has emerged as a pivotal theme with a strong potential for the creation of economic opportunities, while simultaneously promoting environmental and ecological conservation.

The four Sections of this volume of Maritime Perspectives, entitled *"India's Blue Economy Transition"*, seek to illuminate the several pathways that lead toward a resilient blue economy, through a comprehensive examination of multiple themes.

The opening Section addresses issues related to shipping, shipbuilding and ship recycling, each of which is not only a strength area of India, but is also a critical component of sustainable economic development. The six articles in this section serve admirably to highlight the multifaceted nature of these industries, showcasing their potential to drive economic security while adhering to exacting environmental standards.

These six articles also provide for a natural segue into the second section of this volume, which explores the ongoing journey of India's shipping sector as it seeks to transition to clean energy — a process that is as ambitious as it is necessary. The main article within this section explores the potential of ammonia and hydrogen as viable fuel options, providing a comparative analysis that informs policymakers and industry stakeholders alike. The examination of natural gas as a bridge-fuel underscores the importance of a diversified energy portfolio that is supportive of a carefully calibrated shift within the shipping sector, towards more sustainable fuel-alternatives. This section accordingly incorporates a critical review of Vikram Singh Mehta's edited book, *"The Next Stop: Natural Gas and India's Journey to a Clean Energy Future"*.

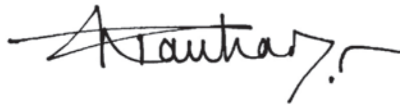
The maritime tourism sector has witnessed significant growth, driven by an exponential increase in the number of tourists who are seeking unique experiences by travelling not just along the coastline of India's mainland and its island chains, but also opting for cruise-ship touristic experiences at sea. Accordingly, the three articles that comprise Section Three address the critical importance of sustainable tourism practices in enhancing the resilience and profitability of seaports. The Section identifies innovative strategies for the integration of tourism with port management, emphasising the need for sustainable development that benefits local communities while preserving the marine environment. A carefully designed, adroitly executed, and environmentally sensitive thrust towards maximising seaport tourism can serve as a catalyst for economic revitalisation, particularly in regions heavily reliant upon maritime activities. By fostering healthy partnerships between local governments, businesses, and the tourism sector, ports can enhance their attractiveness as destinations while ensuring that the ecological integrity of coastal areas is maintained. This holistic approach to tourism and port management is vital for creating sustainable economic opportunities that align with broader environmental goals.

Obviously, the maritime sector cannot be immune to the impacts of climate change, given the significant threat that is posed to coastal communities, marine biodiversity, and global trade routes. The three articles in the fourth and concluding Section of this volume, accordingly, provide critical insights into the challenges and opportunities presented by climate change, focusing on the need for adaptive strategies and innovative solutions. The ongoing battle against climate change is exemplified by initiatives such as the Panama Canal's efforts to mitigate environmental impacts while maintaining its operational efficiency. Furthermore, the assessment of coastal erosion and adaptation measures highlights the necessity for comprehensive planning and investment in sustainable coastal management practices. As one strives for a holistic Blue Economy framework, the adoption of high-level principles by international bodies such as the G20 becomes crucial. Sustainable practices within the maritime sector are aligned with the United Nations' Sustainable Development Goals, particularly those related to climate action and the conservation of marine resources are also covered in this section. Moving forward, it is crucial that we foster a collaborative spirit amongst policymakers, industry stakeholders, and researchers. Only by working together can we ensure that the benefits of the Blue Economy are shared equitably and that the principles of environmental justice are upheld.

By harnessing the collective wisdom and expertise presented in the articles that comprise this volume, one can perceive a realistic future in which economic prosperity and environmental stewardship go hand in hand. Let us embrace this vision and redouble our efforts to transition to a regional blue economy that is not only sustainable but one that is also resilient, innovative, and inclusive.

It is hoped that the consolidated expertise available in this volume will serve as a ready guide for policymakers, industry stakeholders, and researchers alike, in their common endeavour to harness the vast potential of India's maritime resources while simultaneously ensuring that environmental integrity is maintained.

Jai Hind!



Vice Admiral Pradeep Chauhan
AVSM and Bar, VSM, IN (Retd)
Director-General
National Maritime Foundation

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Blue Economy: Shipping, Ship Building & Ship Recycling

Navigating Economic Security through Shipbuilding

Admiral Karambir Singh (Retd) and Commander Y Hemanth Kumar

The international shipping lanes that crisscross the vast expanse of the world's oceans serve as the great highways of India's trade endeavours, carrying nearly 95 per cent of her trade by volume and 68 per cent by value. However, beneath this impressive statistic lies a concerning reality: KPMG [1] reports that merely 8 per cent of this trade is carried on Indian-flagged or owned vessels, leaving the majority to be transported by foreign-flagged ships. An analysis of the prevalence of Chinese-built or controlled vessels in Indian shipping becomes imperative, given the increasingly influential role that China holds in the shipbuilding market. As of 2022, China commanded an imposing 47 per cent of the global shipbuilding industry, which surged by 15.5 per cent within that year alone, as reported by Clarkson.[2]

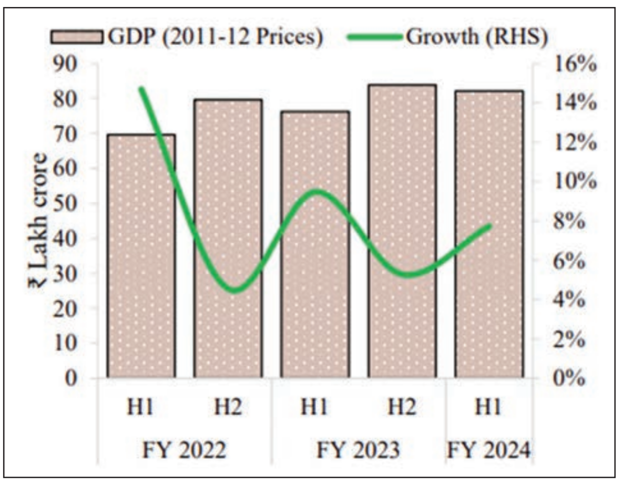
Reports [3] also throw light on an emerging trend wherein Indian entrepreneurs find an advantage in Chinese funding, utilising debt or leasing arrangements to shift assets beyond the jurisdiction of Indian shipping regulations. The allure of lower interest rates and a well-developed lease financing ecosystem has made Chinese financiers a preferred choice for shipping capital. The practice of utilising foreign-built vessels may not in itself be a cause for concern. However, as the ship-finance landscape becomes increasingly dominated by leasing models, the situation takes on a more intricate hue. The ownership of vessels being vested in entities from adversarial nations, while chartering is managed by others, has direct and cascading repercussions on India's trade dynamics and subsequently, its economic security. With growing seaborne trade, India has a significant exposure to marine freight rates. As per reports, every year an estimated USD 75 Billion[4] is paid to foreign shipping companies, impacting India's foreign exchange reserves. This translates to approximately 93 per cent of Indian-origin or international destination cargo shipments and 39 per cent of Indian cargo is shipped on foreign vessels.[5]

It is therefore imperative to strengthen India's shipbuilding industry, as it extends beyond the realm of business and economic interests, into matters of security and strategy. Yet, the path towards enhancing shipbuilding is rife with complexities, interwoven with the broader shipping sector and the global economy. Shipowners and shipping enterprises will only order new vessels if it is profitable, which is in turn subject to the dynamics of the global economy, chartering contracts, and geopolitical events. This article embarks on an exploration of Indian shipbuilding within the expansive framework of its economy. By examining the intricate challenges and impediments that surround this domain, including problems associated with ship financing, the aim is not to offer tailor-made solutions but rather to spark deliberation and discourse. The labyrinthine nature of this issue underscores the importance of a nuanced perspective, necessitating collaborative engagement to chart a path ahead.

State of the Indian Economy and Shipbuilding

As per the Half-yearly Economic Review[6] of November 2023, India's GDP grew by 7.7 per cent in H1 of FY 24 (Apr-Sep 23). Supply chains eased, global inflation declined, and Advanced Economies (AEs) showed resilience. The Government of India's measures have moderated due to stable and declining core inflation. The Government's capital expenditure has accelerated the investment rate. Prudent fiscal policies amidst the fiscal risks prevailing globally are supporting the country's economic

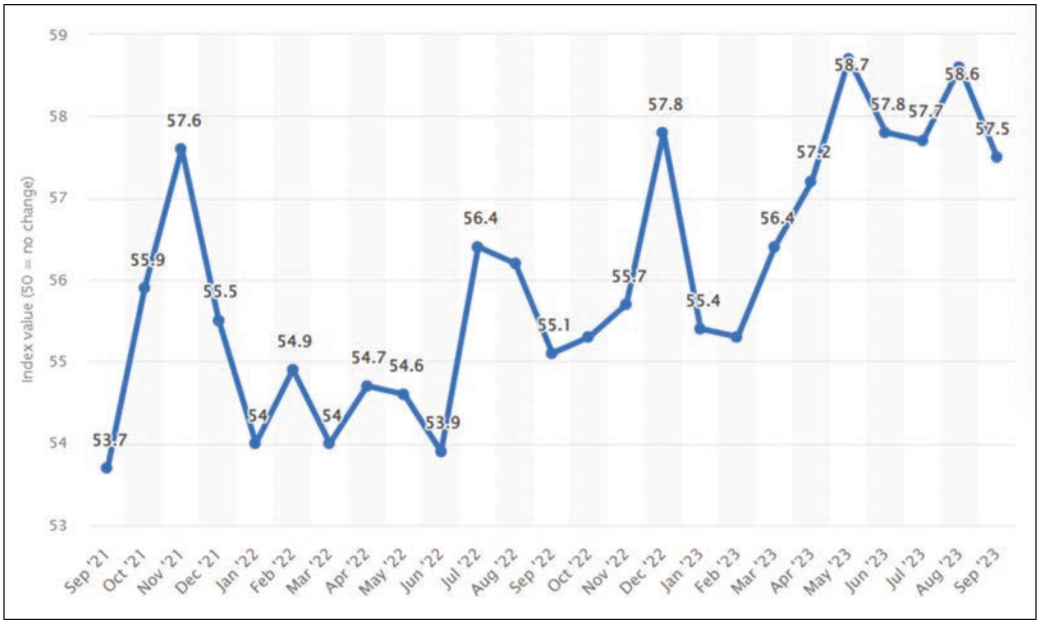
Figure 1: India's GDP in FY 24



Source: MER- November 2023

growth prospects. As a result of this macroeconomic stability, India is expected to grow at 7.3 per cent [7] during the current fiscal year.

Figure 2: India's Manufacturing PMI



Courtesy: Statista [9]

The impact of India's macroeconomic stability is also evident in India's manufacturing sector which showcased an impressive performance. The seasonally adjusted Purchasing Managers' Index® (PMI®)[8] rose to 57.5 in September 2023 from 55.4 in January 2023, indicating the strongest improvement in the health of the manufacturing sector since September 2021.

This growth was driven by robust demand conditions, with factory orders rising at the fastest pace since September 2021, and a surge in sales that paved the way for stronger increases in production, employment, and quantities of purchases. Additionally, the manufacturing sector witnessed record accumulation in input inventories, showcasing better preparedness in managing supply chains. Despite generally subdued global demand for inputs, the manufacturing sector managed to control input price inflation, leading to a solid and quicker increase in output charges.

Furthermore, exports played a vital role in boosting total new orders, with companies registering the quickest expansion in international sales in six months. Despite a robust economy and manufacturing sector, the landscape in the shipbuilding industry presents a more sobering picture. The Annual Report (2022-23) [10] of the Ministry of Ports, Shipping & Waterways, stated that "*the lack of infrastructure in the country due to the collapse of private shipyards, resulted in the erosion of capacity and no proper financing system became a big deterrent to attract the attention of the leading ship owners and market players*". While shipyards in China, South Korea, and Japan delivered 38.1, 24.8, and 22.5 million DWT of ships respectively in the year 2021[11], the Indian shipbuilding industry delivered a meagre 0.03028 million DWT (30.28 thousand DWT) [12] during 2020-21. To appreciate this issue, it is important to first examine the initiatives already taken by the Government of India (GoI) for the shipbuilding industry.

Government of India's Initiatives for Shipbuilding Sector

The Government of India (GoI) has taken several proactive initiatives to bolster the shipbuilding sector in the country and foster self-reliance. Notably, the Shipbuilding Financial Assistance (SBFA),[13] approved in 2015,[14] offers financial support to Indian shipyards through a 20 per cent grant based on the contract price or fair price for each vessel built, valid for ten years from 2016 to 2026. To further enhance opportunities for domestic shipyards, the Right of First Refusal policy mandates government agencies and CPSUs to prioritize Indian shipyards for vessel procurement or repairs until 2025, with certain guidelines facilitating small shipyards' participation. Recognizing the strategic importance of shipyards, they have been granted infrastructure status,[15] allowing access to flexible long-term project loans, lower interest rates from Infrastructure Funds, relaxed External Commercial Borrowings (ECB) norms, and infrastructure bond issuance for working capital needs. Moreover, the Standard Operating Procedures for Chartering of Tugs[16] and Procurement of Deep-Sea Fishing Vessels under the Pradhan Mantri Matsya Sampada Yojana (PMMSY)[17] aim to promote small and medium shipyards.

In line with the vision of self-reliance and promoting Indian tonnage and shipbuilding, the criteria for granting the Right of First Refusal (ROFR)[18] in chartering vessels have been revised. The preference is now given to vessels that are Indian-built, Indian-flagged, and Indian-owned, thus encouraging the use of Indian-flagged vessels and fostering the growth of indigenous shipbuilding capacity. The Public Procurement (Preference to Make in India)[19] policy, revised in 2020, discourages issuing global tender enquiries for public procurement of goods and services below the value of INR 200 crores. This move supports domestic shipyards by potentially increasing orders and promoting the "Make in India" initiative. An important factor contributing to escalated costs in Indian shipbuilding is the imposition of taxes and duties on input material used in shipbuilding. To mitigate the cost disparity faced by Indian shipyards and foster the growth of the domestic shipbuilding industry, the GoI has exempted customs and central excise duties on input material used in shipbuilding.[20] Furthermore, through amendments to the Insolvency and Bankruptcy Code[21] the GoI has expedited taking over (or is in the process) of several private shipyards (for example, Tebma Shipyard (Malpe) by CSL, the ongoing takeover of ABG Shipyard & Reliance Naval) that have been shut down for many years owing to financial distress.

Despite these comprehensive and forward-looking initiatives which demonstrate the Government's commitment to creating a conducive environment for shipbuilding growth, the industry, as a whole, so far has not been able to fully capitalize on these initiatives. As of March 2023, reports[22] indicate that out of the substantial Rs. 4000 Cr corpus allocated for the Shipbuilding Financial Assistance Package, only a few Shipyards have been able to effectively leverage the subsidy, amounting to a mere Rs. 261 Cr. Looking back at the shipbuilding manufacturing discussed earlier, it becomes glaringly apparent that this predicament arises from the shipbuilding industry's inability to attract large-scale commercial orders involving high DWT vessels (with the closure of high-capacity private shipyards, currently private shipbuilding is confined to small vessels), despite the support from Government and presence of domestic demand for ships.

Domestic Demand for Ships

As brought out in earlier reports,[23] India's overseas commercial shipping fleet has been predominantly foreign-controlled. Consequently, Indian flagged/controlled vessels account for only 8% of the Indian export and import freight market. The fraction of Indian-flagged ships built domestically exposes the dearth of orders in the commercial shipbuilding sector. From various perspectives such as economy, trade, energy security, and shipbuilding, India must reduce its dependence on foreign-controlled and foreign-built ships for sea trade requirements. Another critical issue highlighted in the report pertains to the aging profile of India's overseas fleet. Data reveals that over 50 per cent of the fleet, both in terms of number and gross tonnage, is over 15 years old, with nearly 35 per cent surpassing the 20-year mark. In contrast, the average age of the international fleet stands at 15.06 years. Consequently, at least 50 per cent of India's existing overseas fleet would necessitate replacement in the next five to ten years.

It is important to note that as per the DG Shipping order,[24] vessels over 20 years will not be allowed to operate in the Indian Waters. On the coastal and inland waterways front, the Government has taken cognisance of their cost efficiency and the *Sagarmala* program targets an increase in the share of waterways to about 12 per cent by 2025. In the FY19, coastal shipping accounted for about 120 million tons per annum (MTPA) of cargo transportation, and the GoI has targeted an increase to about 230 MTPA by 2025. Further, the Inland Waterways Authority of India (IWAI) has declared 111 rivers across the country as national waterways for cargo movement. To achieve this target and sustain this growth, it is estimated that India's existing coastal and inland waterway fleet would need to be tripled in the next 5 to 10 years. This has the potential to create a shipbuilding demand of about 12.75 million Compensated Gross Tonnage (CGT). In the defence sector, as per the Maritime Capability Perspective Plan (MCPP), the Indian Navy's goal to become a 170-ship force[25] by the end of this decade generates a substantial demand for defence shipbuilding.

The positive aspect to highlight is the persistent domestic demand for ships, which not only remains steadfast but is also predicted to experience substantial growth, offering a much-needed buffer between the Indian shipbuilding industry and the global demand for ships. However, the private sector has yet to attain a competitive edge in the global market. Consequently, it becomes imperative for the industry to expeditiously rectify this situation. It is worth noting that, unlike other sectors, the expansion of shipbuilding not only influences the industry from a business point of view but also exerts a profound impact on the developmental aspects of the Indian economy.

Economic Impact of Shipbuilding

The Economic Survey[26] 2022-23 highlighted that the shipbuilding industry boasts a high employment multiplier of 6.48, indicating its capacity to generate a substantial number of job opportunities. Furthermore, the shipbuilding sector emerges as a potential solution to the issue of mass employment for migrating workers. As workers transition from traditional agricultural activities to more industrial settings, the shipbuilding industry can serve as a viable alternative to the construction sector, offering abundant job prospects and avenues for skill development. The economic implications of the shipbuilding industry extend beyond job creation, as it exhibits a notable investment multiplier effect. By employing a conservative Marginal Consumption to GDP Ratio (MCGR) of 0.45, the estimated investment multiplier is approximately 1.82. This implies that every unit of capital invested in shipbuilding stimulates economic activity and contributes to the growth of related industries. Such a multiplier effect is instrumental in driving India's macroeconomic development. Moreover, the expansion of the shipbuilding sector fosters the development of Micro, Small, and Medium Enterprises (MSMEs). The increased demand for ancillary products and services necessitates the growth of supporting industries, thereby promoting economic diversification and nurturing a culture of innovation and entrepreneurship.

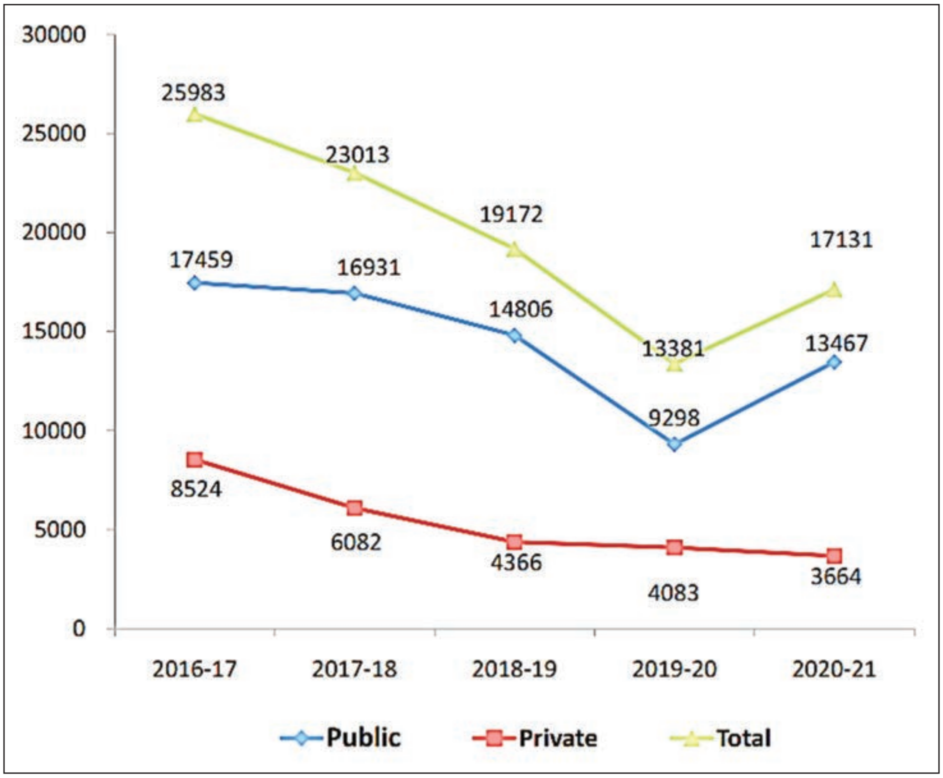
This symbiotic relationship between the shipbuilding industry and MSMEs further strengthens India's macroeconomic framework, making it more resilient and self-reliant, aligning with the vision of *'Aatmanirbhar Bharat'*. The shipbuilding industry's contributions to employment generation, investment stimulation, and the growth of MSMEs make it a vital component of India's economic fabric. By rising to the challenges, shipbuilding holds the potential to emerge as the vanguard of India's growth narrative in the forthcoming years. Its ability to fulfill this role hinges upon a concerted effort from the industry players to bolster its competitiveness and seize the opportunities presented by the growing demand for ships both domestically and internationally. An unrelenting focus on innovation, quality, and efficiency will undoubtedly bekey in positioning the Indian shipbuilding sector as a force in the global arena.

Challenges Faced by the Shipbuilding Industry in India

In a typical shipbuilding project, nearly 70-80 per cent constitutes material costs. Of this, about 30-40 per cent is steel cost which is sourced indigenously. Nearly 60-65 per cent[27] cost is for electronics, engineering and electrical equipment.[28] However, critical components like propellers, marine gas turbines, high-capacity main engines, shafting, gear boxes, high-capacity diesel generators, control systems, etc are mostly imported. Although Indian manufacturing exists for some of these items, their adoption has been limited. While the absence of domestic manufacturing capabilities is a problem for these items, dumping by foreign vendors at lower costs of some items is adversely impacting the domestic industry. The remaining 20-30 per cent constitutes labour and material overheads. As per studies,[29] in India, the labour cost per worker is low and is of the order of $1,192 per year which is 10-20 times lower than the labour rates in the major shipbuilding nations. However, this low labour rate does not translate into lower ship costs, since the labour productivity is very low.

Studies indicate that[30] the labour productivity value for India is approximately $11,134/employee and the values in South Korea and Japan are $1,22,994/ employee and $1,51,487/employee respectively, i.e., approximately 10 times lower than the major shipbuilding nations. All these translate to about 20-25 per cent cost advantage for major shipbuilding nations vis-à-vis India. Another significant challenge faced by Indian shipbuilders is their relatively longer construction cycles. Unlike leading shipbuilding nations that construct vessels based on anticipated orders, Indian shipbuilders experience delays in design, planning, construction, and delivery, hindering their ability to meet market demands promptly. Additionally, the presence of a thriving resale market for ships in other Asian nations, such as China and South Korea, poses stiff competition for Indian shipbuilders. These countries offer vessels at significantly lower prices compared to new builds and even engage in the re-manufacturing of old ships to extend their operational life. Lastly, the diverse availability of a particular ship (like AHTS, PSV) at various price points globally creates a challenge for Indian shipbuilders to match the offerings present in the market, as different types of ships correspond to different quality levels. All these advantages

Figure 3: Decreasing employment trend in Shipbuilding and ship repair in India



Source: MoPSW[31]

lead to higher-order books in other countries which enable their shipyards to order all the material in bulk, which adds to cost advantage. These challenges faced by the Indian shipbuilding sector have significantly hampered its ability to fully capitalize on its high economic multiplier potential. This primarily translates into the dearth of substantial orders, which, in turn, has led to a noticeable decline in employment opportunities both in the shipbuilding and ship repair domains.

Ship Financing

In addition to the aforementioned concerns, the domain of ship financing is fraught with intricate challenges that warrant examination. The issue of high working capital looms prominently in shipbuilding ventures during the construction phase, manifesting itself at around 20-25 per cent.[32]. Studies have also shown that there are instances where this figure is an even higher percentage of 35-40 per cent, signifying a heightened capital demand for certain classes of ships.[33] Typically, this requirement finds recourse in the form of bank loans, entailing a rather onerous financial burden. Recent studies indicate prevailing interest rates of approximately 10-10.5% for such loans,[34] in stark contrast to the more favourable rates of 4-8% in major shipbuilding nations.[35]

A further complexity is introduced by the cycles inherent in the shipping/shipbuilding business. Regulations by central banks and evolving market dynamics necessitate that banks prioritise a robust debt-to-equity ratio exhibited by a prospective shipyard before extending financial support. This caution is uniformly exercised across banks. Comparable to the evolution of alternative financing avenues within sectors such as infrastructure and real estate, diversification within shipbuilding is equally conceivable. Mechanisms such as capital markets, structured finance, or direct lending could potentially foster an environment of sustained financial accessibility throughout the business cycle. In scenarios wherein the shipyard is a larger business conglomerate, securing requisite debt might happen with relative ease. However, the landscape changes distinctly for nascent start-up shipyards. In such instances, envisioning the establishment of a company, boasting an annual revenue of 150 Cr, would necessitate a capital infusion of approximately 200 Cr. Consequently, a significant portion, around 40-50 Cr, must be committed as equity – a collaborative manifestation of personal and partner funds. The residual sum, a substantial 150 Cr, must be sought in the form of debt, invariably supported by collateralized assets, including the vessel under construction.

Debt Financing

This scenario engenders a debt-equity ratio of 4:1, or perhaps even more. This scenario contrasts starkly with the academically advocated preference of maintaining a 2:1 debt-equity ratio, an axiom advocated within the business pedagogy. For those inclined to traverse higher-risk terrain, the spectrum might extend towards 2.5 or even 3. As the debt quotient escalates, so too does the onus of servicing interest obligations, potentially diverting entrepreneurial efforts towards debt servicing as opposed to substantive business expansion. Thus, a prudent fiscal posture encourages minimizing debt. Within capital-intensive domains like shipbuilding, instances of a 4:1 debt-equity ratio may not be unheard of. Yet, this milieu is characterised by meagre margins and the spectre of order scarcity, coupled with the latent risk of contract cancellations, collectively fostering an aversion to excessive debt within both banking and fund institutions. Further, it needs to be seen how the introduction of Basel-3 standards[36] for commercial banks by RBI would impact the leverage ratios with respect to shipbuilding debt financing.

Equity Financing

Consequentially, direct equity infusion assumes significance. Mutual funds have a restriction of 5-10 per cent NAV in unlisted equities[37], where most nascent private shipyards fall. Under such circumstances, avenues for recourse are limited to the formation of an Alternate Investment Fund (AIF). Venture Capital including Angel Funds and Infrastructure funds which fall under Category-1 AIFs[38] could be used to finance early-stage investments, especially when shipbuilding has now been given the infrastructure status. Whereas the working capital needs could be financed through Category-2 AIFs like Private Equity (PEs).[39] However, the viability of venture capital within the shipbuilding sector appears uncertain as of now, given the inherently capital-intensive nature of the industry and the less evolved shipbuilding ecosystem in India, which would not attract venture capitalists. On the other hand, the private equity option also comes with its attendant complexities. Private equity investors exact multifarious terms and stipulations, spanning assured returns and strategically devised exit mechanisms. It is a realm that demands a degree of confidence and resilience from an entrepreneur willing to navigate such terrain.

To tackle equity financing challenges within infrastructure projects, the GoI took a significant step by establishing the National Investment and Infrastructure Fund (NIIF). This entity operates as an AIF functioning akin to a Quasi-Sovereign Wealth

Fund (SWF). Its primary objective is to extend financial support to companies engaged in financing infrastructure projects that require long-term capital. NIIF offers an attractive avenue for private equity investors, presenting them with valuable investment prospects. Since shipbuilding has been granted infrastructure status, NIIF could bring in several benefits. However, it's noteworthy that NIIF currently does not encompass the shipbuilding sector. This omission could be attributed to the shipbuilding industry's relatively nascent ecosystem and the inherent risks associated with it. As can be seen, there is no dearth of financial instruments for Ship financing. The challenge lies in attracting investment through them into shipbuilding. But the only way to achieve this is to first de-risk the business itself and increase the productivity of the industry.

Ship Finance Leasing & Production Linked Incentive (PLI Scheme) for Shipbuilding

To achieve this, in addition to the existing initiatives, two potential interventions could be the adoption of a Ship finance leasing model and Production Linked Incentive (PLI) scheme, to improve the shipbuilding ecosystem in India. Such measures would not only de-risk the shipbuilding business and encourage efficient shipyards but also would conform to the regulatory prescriptions of the World Trade Organization (WTO), thus fostering a harmonious confluence of economic pragmatism and international compliance.

Ship Finance Leasing

Ship finance leasing could be one of the solutions to the financing predicaments faced by prospective investors in shipping and shipyards in India. This financing model involves separating ship ownership from its usage rights. The shipowner gains ownership through purchase, while the shipping company or a charterer enjoys the ship's usage rights through a lease contract. This approach addresses the capital turnover pressure experienced by shipping companies. Further, this model of financing reduces capital pressure on the shipyards as well, on whom the shipbuilding contract is placed. As a result, the shipping company is derisked from owning a capital-intensive asset like a ship while the shipyard's exposure to the risks emanating from shipping operations, chartering, and freight markets is minimized to a great extent. As a result, it also opens up investment opportunities for potential investors through financial instruments.[40]

Production Linked Incentive (PLI) Scheme

While the current initiatives by the GoI do effectively consider the macro-economic dimensions of the shipbuilding industry, there remains a need to address the productivity challenges intrinsic to the Indian shipbuilding sector. A potential Production Linked Incentive (PLI) scheme for the shipbuilding industry could encompass a range of incentives aimed at fostering growth and competitiveness. This scheme might involve output-based rewards, where shipbuilders receive incentives based on the quantity and type of ships they produce, encouraging higher production levels. Additionally, investment incentives could be granted to those who invest in modernising their facilities and adopting advanced manufacturing technologies. Quality and innovation could also be incentivised, promoting shipbuilders to create high-quality, innovative vessels that meet global standards. Export-oriented benefits could drive shipbuilders to manufacture ships for international markets, boosting the country's presence in the global shipbuilding sector. The scheme might also offer rewards for generating employment opportunities, contributing to economic expansion. Encouraging energy efficiency and environmentally friendly practices could align with sustainability goals. Moreover, incentives linked to skill development, research and development, and transparent reporting mechanisms could further bolster the industry's capabilities and accountability.

An important provision that merits consideration within this PLI scheme is the promotion of equipment manufacturing for shipbuilding. Although this might initially seem ambitious, it's important to acknowledge that the path to global competitiveness for Indian shipbuilders necessitates a departure from reliance on imported equipment. Furthermore, it's crucial to recognize that if the Indian shipbuilding industry chooses to await the development of domestic equipment manufacturing capabilities, the industry will inevitably remain susceptible to the inefficiencies inherent in the equipment sector, predominantly the R&D ecosystem. This implies that no matter how enhanced the productivity of shipyards become, they would remain vulnerable to the limitations of the equipment industry. Crafting such a scheme requires careful consideration of industry dynamics and policy objectives to ensure its effectiveness and positive impact on the shipbuilding sector.

Conclusion

The crucial interplay between the shipbuilding industry, economic security, and strategic interests of India should be recognised. While the maritime sector remains a cornerstone of India's trade and economic growth, the preponderance of foreign-built and controlled vessels poses significant challenges. The shipbuilding industry's potential to drive economic development, create jobs, and foster innovation is evident, yet various obstacles hinder its full realisation. The GoI's initiatives to support shipbuilding demonstrate a commitment to fostering self-reliance and bolstering domestic capabilities. However, the industry grapples with complex challenges, including dependency on imported equipment, labour productivity, construction cycles, and competition from foreign shipyards.

Effective solutions demand a multi-pronged approach that involves fostering domestic manufacturing, enhancing productivity, and exploring innovative financing mechanisms. The proposed ideas, such as a Production Linked Incentive (PLI) scheme and ship finance leasing, hold promise in addressing the financial hurdles faced by shipbuilders. A PLI scheme could incentivize increased production, modernization, quality, and innovation, thus propelling the industry forward. Ship finance leasing, on the other hand, offers a potential remedy for the capital turnover pressure and de-risk the owners, shipbuilders, and shipping companies who could attract a wider range of investors. As India strives for self-reliance and aims to reduce its dependence on foreign-built and controlled ships, collaborative efforts between the government, industry players, and financial institutions will be crucial. The shipbuilding sector's growth not only holds economic significance but also contributes to India's strategic autonomy, ensuring a secure and resilient maritime trade infrastructure. In navigating the intricate waters of shipbuilding, economic security, and strategic aspirations, a comprehensive and adaptable approach is paramount. By fostering innovation, enhancing competitiveness, and embracing innovative financing models, India's shipbuilding industry can truly set sail towards realizing its potential as a cornerstone of the nation's economic growth and security in the maritime domain.

Disclaimer: Views expressed are of the authors and do not necessarily reflect the views of the Government of India.

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ENDNOTES

1 "Leveraging Defence Ship Building to Catalyse India's Shipbuilding Industry," 2020, https://www.npcindia.gov.in/NPC/Uploads/publication/Leveraging defence shipbuilding_LR371892.pdf

2 Niels Rasmussen, "Chinese Shipyards Hit Record 47% Market Share in 2022," February 15, 2023, https://www.bimco.org/news-and-trends/market-reports/shipping-number-of-the-week/20230215-snow#:~:text=In 2022%2C Chinese shipyards reached,Japanese and South Korean shipyards

3 Anil Delvi, "Building an India Owner Merchant Fleet," December 26, 2019, https://www.gatewayhouse.in/india-owned-merchant-fleet/#_ftn1

4 IFSCA, "SAFAL," 2021, https://www.ifsca.gov.in/Document/ReportandPublication/safal-report-final-2021-10-28-signed-live1212112021032138.pdf

5 IFSCA, "SAFAL," 2021, https://www.ifsca.gov.in/Document/ReportandPublication/safal-report-final-2021-10-28-signed-live1212112021032138.pdf

6 Economic Division, "Half-Yearly Economic Review 2023-24" (New Delhi, 2023), https://dea.gov.in/sites/default/files/Half-Yearly Economic Review FY24_November 2023.pdf

7 MoSPI, "First Advance Estimates of National Income, 2023-24" (PIB, 2024), https://pib.gov.in/PressReleasePage.aspx?PRID=1993550

8 Statista, "India: Purchasing Managers' Index (PMI) from September 2021 to September

2023," n.d., https://www.statista.com/statistics/275297/purchasing-managers-index-pmi-in-india/

9 Statista, "India: Purchasing Managers' Index (PMI) from September 2021 to September 2023," n.d., https://www.statista.com/statistics/275297/purchasing-managers-index-pmi-in-india/

10 MoPSW, "Annual Report" (New Delhi, n.d.),41. https://shipmin.gov.in/sites/default/files/Annual Report 2022-23 English.pdf

11 IFSCA, "SAFAL," 2021, https://www.ifsca.gov.in/Document/ReportandPublication/safal-report-final-2021-10-28-signed-live1212112021032138.pdf

12 MoPSW, "Annual Report" (New Delhi, n.d.), 41. https://shipmin.gov.in/sites/default/files/Annual Report 2022-23 English.pdf

13 "Guidelines for Shipbuilding Financial Assistance Policy (SBFAP) - Amendment Regarding.," Pub. L. No. SY-16023/6/2015-SBR, Part-1, 43 (2021), https://shipmin.gov.in/sites/default/files/Amended guidelines.pdf

14 "Guidelines for Implementation of Shipbuilding Financial Assistance Policy, (2016-26)," Pub. L. No. SS/MISC(15)/2015 (2016), https://www.dgshipping.gov.in/writereaddata/ShippingNotices/201607131104291790870shippingbuilding_financial_asstance_policy_04072016.pdf

15 "Infrastructure Status to Shipyard Industry," *PIB*, March 10, 2016, https://pib.gov.in/newsite/PrintRelease.aspx?relid=137711#:~:text=Infrastructure status would enable Indian, and invest in capacity expansion

16 "SOP for Charter of Tugs by Major Ports under Atmanirbhar Abhiyan Policy and Implementation of Public Procurement (Preference to Make in India)," Pub. L. No. SY-13013/1/2020-SBR (2020), https://shipmin.gov.in/sites/default/files/To be uploaded on MOS Website.pdf

17 "Boats for Deep Sea Fishing," *PIB*, March 29, 2022, https://pib.gov.in/PressReleasePage.aspx?PRID=1810959

18 "To Boost Shipbuilding in India , Ministry of Shipping Amends Right of First Refusal (ROFR) Licensing Conditions A Bold Step towards ' AatmaNirbharShipping ' for 'AatmaNirbhar Bharat." PIB. New Delhi, October 2020. https://pib.gov.in/PressReleasePage.aspx?PRID=1666728

19 "Revised Consolidated Instructions Regarding Global Tender Enquiry (GTE) Rule 161 (Iv) for General Financial Rules (GFRs), 2017 up to Rs.200 Cr- Regarding.," Pub. L. No. DPE/7(4)/2017-Fin. (2021), https://dpe.gov.in/sites/default/files/GTE-09-08-2021.pdf

20 "Inputs Used in Ship Manufacturing and Repair Exempted from Customs and Central Excise Duties," *PIB*, December 1, 2015, https://pib.gov.in/newsite/PrintRelease.aspx?relid=132200

21 "IBBI Amends Insolvency and Bankruptcy Board of India Regulations, 2017," *PIB*, June 15, 2022, https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1834292#:~:text=The Insolvency and Bankruptcy Code, insolvency professional agencies and information

22 "Rs 4,000 Cr State-Aid for Shipbuilding Go Abegging as Yards Collapse," *Economic Times*, May 1, 2023, https://infra.economictimes.indiatimes.com/news/ports-shipping/rs-4000-cr-state-aid-for-shipbuilding-go-abegging-as-yards-collapse/99902559

23 "Leveraging Defence Ship Building to Catalyse India's Shipbuilding Industry," 2020. https://www.npcindia.gov.in/NPC/Uploads/publication/Leveraging defence shipbuilding_LR371892.pdf

24 DG Shipping, "DGS Order on Age Norms and Other Qualitative Parameters w.r.t Ships," Pub. L. No. F.No.16-17011/5/2022-SD-DGS (2023), https://www.dgshipping.gov.in/WriteReadData/News/202302270559032302259DGSOrder06of2023onAgeNorms.pdf

25 Dinakar Peri, "Navy on Course for 170 Ship Force: Navy Vice Chief," *Hindu*, November 16, 2021, https://www.thehindu.com/news/national/navy-on-course-for-170-ship-force-navy-vice-chief/article37525244.ece

26 Economic Survey, "Shipbuilding Sector: Achieving Self-Reliance and Promoting Make in India" (New Delhi, 2023)

27 "Shipbuilding Industry Capable of Generating Mass Employment in Remote, Coastal and Rural Areas: Shri Mansukh Mandaviya," *PIB*, November 25, 2019, https://pib.gov.in/Pressreleaseshare.aspx?PRID=1593424

28 "Leveraging Defence Ship Building to Catalyse India's Shipbuilding Industry," 2020. https://www.npcindia.gov.in/NPC/Uploads/publication/Leveraging defence shipbuilding_LR371892.pdf

29 DSIR, "Shipbuilding : Productivity & Efficiency Benchmarking," n.d., https://www.dsir.gov.in/sites/default/files/2019-11/9_9.pdf

30 DSIR, "Shipbuilding : Productivity & Efficiency Benchmarking," n.d., https://www.dsir.gov.in/sites/default/files/2019-11/9_9.pdf

31 Transport Research Wing, "Statistics of India's Ship Building and Ship Repairing Industry" (New Delhi, n.d.)

32 DSIR, “Shipbuilding : Productivity & Efficiency Benchmarking,” n.d., https://www.dsir.gov.in/sites/default/files/2019-11/9_9.pdf

33 Dr. A.Mourougane, “Present Scenario of Ship Building Industry in India,” *Journal of Development Economics*, 2020, https://www.cdes.org.in/wp-content/uploads/2020/10/Dr.-A.Mourougane.pdf

34 DSIR, “Shipbuilding : Productivity & Efficiency Benchmarking,” n.d., https://www.dsir.gov.in/sites/default/files/2019-11/9_9.pdf

35 Dr. A.Mourougane, “Present Scenario of Ship Building Industry in India,” *Journal of Development Economics*, 2020, https://www.cdes.org.in/wp-content/uploads/2020/10/Dr.-A.Mourougane.pdf

36 RBI, “Master Circular - Basel III Capital Regulations,” Pub. L. No. RBI/2023-24/31 DOR.CAP.REC.15/21.06.201/2023-24 (2023), https://doi.org/10.4337/9781784719227.00011

37 SEBI, “Securities and Exchange Board of India (Mutual Funds) (Amendment) Regulations, 1999” (1999), https://www.sebi.gov.in/sebi_data/commondocs/CIRMF092000_h.html#:~:text=A mutual fund scheme shall,the NAV of the scheme

38 GOI, “Securities and Exchange Board of India (Alternative Investment Funds) Regulations, 2012,” The Gazette of India (2012), https://www.sebi.gov.in/legal/regulations/jan-2023/securities-and-exchange-board-of-india-alternative-investment-funds-regulations-2012-last-amended-on-january-9-2023-_67273.html

39 GOI, “Securities and Exchange Board of India (Alternative Investment Funds) Regulations, 2012,” The Gazette of India (2012), https://www.sebi.gov.in/legal/regulations/jan-2023/securities-and-exchange-board-of-india-alternative-investment-funds-regulations-2012-last-amended-on-january-9-2023-_67273.html

40 Xionghui Wen, “Research on Financing Methods of China’s Shipbuilding,” *Theoretical Economics Letters* 08, no. 14 (2018): 3116–40, https://doi.org/10.4236/tel.2018.814194

Assessing India-US "Master Ship Repair Agreements" (MSRAs)

Ms Anuttama Banerji and Vice Admiral Pradeep Chauhan

In July of 2023, a "Master Ship Repair Agreement" (MSRA) involving the US Navy was concluded at Kattupalli, Tamil Nadu, for the very first time in India. It is of great consequence to note that it was not a Government of India's Public Sector Undertaking (PSU) shipyard but rather, a private one, owned by M/s Larsen & Toubro (L&T), which stood at the vanguard of this momentous development.[1] This was followed, in September of 2023, by a second MSRA involving an Indian shipyard, this time the venerable Mazagaon Dock Shipbuilders Limited (MDL), Mumbai.[2] Most recently, in April of 2024, Cochin Shipyard Limited (CSL), another Indian Public Sector Undertaking (PSU), concluded a third MSRA with the US Navy.[3]

This article attempts to provide the reader with an understanding of MSRAs and the potential they hold for India. It also seeks to identify how India could potentially leverage the concept of MSRAs to consolidate her position as an Indo-Pacific hub for ship repairs.

Master Ship Repair Agreements

MSRAs are formal agreements between the US federal government and commercial contractors who are in possession of prior certifications to perform ship repair work on ships of the USA's Department of Defence — specifically, those operated by the Military Sealift Command (MSC), all of which are non-commissioned the US Navy "support vessels" with civilian crews and bear the prefix "USNS" (as opposed to commissioned, combatant warships of the US Navy, which are manned by uniformed US Navy crews and bear the prefix "USS"). This is an important distinction that needs to be borne in mind in managing Indian expectations that the MSRAs will, at a future point in time, enable Indian shipyards to carry out maintenance, repair, and overhaul (MRO) functions for the US Navy combatant warships.

To place matters in context it needs to be noted that the MSC is the principal provider of maritime logistics to the US Department of Defence. It forms the *naval* component of the USA's "Transportation Command".[4] As one of an overall number of nine "component commands"[5] of the US Navy, the MSC directly supports the Commanders of the US Navy's seven active "Numbered Fleets".[6] Towards this end, the MSC crews, trains, equips, and operates over 130 government and commercially owned as well as chartered vessels for the Department of Defence and other agencies. The MSC fleet includes sealift vessels, tankers, naval auxiliaries, and a variety of special mission and support ships.

MSRAs *"allow mid-voyage US Navy ships to undergo service and repair at Indian shipyards, facilitating cost-effective and time-saving sustainment activities for US military operations across multiple theatres,"*[7] and play a significant role in enhancing maritime security cooperation between India and the United States,[8] especially following the signing of the four "foundational agreements".[9]

However, MSRAs do not currently apply to the US combatant warships (with the prefix "USS") and are limited to the support vessels of the MSC. This is because the US law, specifically "Title 10 of the US Code — Section 8680",[10] which addresses the *"Overhaul, repair, etc. of vessels in foreign shipyards: restrictions"*, states quite clearly that *"A naval vessel the homeport of which is in the United States or Guam may not be overhauled, repaired, or maintained in a shipyard outside the United States or Guam."* Section 8680 does provide an exception to the US naval vessels *"…classified as a Littoral Combat Ship and operating on deployment"* in which case, "*corrective and preventive maintenance or repair (whether intermediate or depot level) and facilities maintenance may be performed on the vessel (i)in a foreign shipyard; (ii)at a facility outside of a foreign shipyard; or (iii)at any other facility convenient to the vessel"*. This is why one frequently sees an LCS (but not other 'types' of US combatant warships) undergoing repairs in, say, Singapore. That having been recorded, it is technically possible for shipyards outside of the US or Guam to undertake the MRO of the US combatant warships, should the Secretary of the Navy — the equivalent of what might, in India, have (hypothetically) been the Union Minister for the Navy — authorise this under Clause 3 of this very same Section, which states:

> "(3) Notwithstanding paragraph (1), a naval vessel described in paragraph (1) may be repaired in a shipyard outside the United States or Guam if the repairs are—
>
> (A) voyage repairs[11]; or
>
> (B) necessary to correct damage sustained due to hostile actions or interventions."

The foregoing is important in that if the Government of India were to support such a proposal in some suitable high-level bilateral forum (the India-US 2+2 springs to mind) it could lead to a significant enhancement in the brand-positioning of India as a hub for warship repairs. Nation-branding is, of course, critical — a subject that has been extensively and excellently dilated-upon by Shantanu Chakrabarti in his recent and eminently readable book, *Nation Branding in Non-Western Societies.*[12]

To return, however, to the MSRAs themselves, they basically list out the terms and conditions that enable country-specific contractors to bid for actual repair work projects in a free and fair manner, thereby reducing potential administrative hurdles.[13] They enable the US Navy to receive satisfactory repairs of its ships from private sector entities (and foreign public-sector ones as well) that have successfully made out a commercial proposition to undertake such repairs. MSRAs ensure structural competitiveness of the private / public sector industrial base and enable the repair of the US Navy ships at economical rates.[14] In addition, these agreements also include information and clauses associated with issues of mutual concern, such as security, payments, and other potential liabilities.

At the minimum, in order to be awarded a contract under an MSRA, a contractor (indigenous/local or foreign) must have berthing facilities or management control of such facilities.[15] In addition, a request for ship-repair work has to be made from the designated authority/entity for the contractor to undertake the stipulated repairs.[16] Importantly, from the perspective of the contractor, an MSRA contract is deemed to be complete only upon execution of the job order.[17] MSRAs are reviewed every five years but this periodicity may be altered as required.[18]

Potential for India

Within the context of the India-US bilateral partnership, MSRAs need to be viewed — whether through an economic lens or a security one — as important milestones. For one thing, MSRAs have increased India's overall prestige within the international community of States. 'Prestige', as an ideational construct, refers to the perception that other countries have of a nation's worth or value.[19] As Robert Gilpin stated over four decades ago, *"Prestige, rather than power, is the everyday currency of international relations, much as 'authority' is the central ordering feature of domestic society… Whereas power refers to the economic, military, and related capacities and capabilities of a State, prestige refers primarily to the perceptions of other States with respect to a State's capacities and its ability and willingness to exercise its power."*[20] The conclusion of MSRAs has enhanced India's prestige and positioned her as not only as an important ship recycling hub[21] but also as a major centre of ship repairs across the Indo-Pacific. Thus, Indian shipyards are increasingly being viewed as international players that can provide ship repair facilities of the highest order at competitive rates.

Since the shipping sector has deep linkages with a host of auxiliary industries and can contribute significantly to the creation of a collaborative production ecosystem, the MSRAs that have been concluded have, in addition, provided growth opportunities for Indian vendors within ancillary industries to support US naval requirements.[22] In particular, these MSRAs have benefited small businesses, while strengthening supply chain networks. In addition, spinoff benefits have included the generation of large-scale employment opportunities for workers in remote, coastal, and rural areas.[23] At a broader level, MSRAs have fostered greater knowledge-sharing, giving birth to a variety of technological advancements in the maritime domain.

MSRAs are also beneficial in respect of security, as they build on the existing Logistics Exchange Memorandum of Agreement (LEMOA), a key foundational defence agreement that was signed between India and the United States in 2016. As is well known, the LEMOA has enabled, *"ships of one country to replenish their fuel* *stocks in the other country during port calls, exercises and training"* and, by so enabling, has given a significant push to defence and security cooperation between India and the United States.[24] Importantly, these MSRAs enable Indian shipyards, whether in the public sector or the private one, to provide logistic support to the US Navy and ensure supply chain resilience within the Indo-Pacific[25] at a time when a rising Chinese threat continues to be dominant in the region. In this regard, MSRAs, in conjunction with the LEMOA, have expanded logistics coordination between India and the United States within the Indo-Pacific such that the US Navy can complete the requisite repair work on its ships within 90 days, allowing the ships to thereafter return to their established pattern of regional deployment.[26] Since the number of shipyards where US naval ships/vessels can dock for ready maintenance are limited,[27] and given that US shipyards are already stretched in the ongoing US effort construct an enhanced naval fleet to deter armed conflict in the Indo-Pacific,[28] Indian shipyards, with their acknowledged technical skills and their cheap but well-trained work force, can fill the gap in terms of maintenance, repair, and overhaul, and are certainly an attractive proposition. In this sense, *"the ship repair deal (is being viewed) as an exercise in reassurance, confirming that warmer relations between India and the United States are here to stay."* [29] It is important to note that India has, thus far, provided maintenance and repair services to Lewis-and-Clark Class dry-cargo vessels such as the USNS *Charles Drew,* and the USNS *Matthew Perry*,[30] as well as the rescue and salvage ship, USNS *Salvor.*[31]

Finally, MSRAs are also significant in that they have been conceptualised at a time when India is attempting to conclude "Security of Supply Agreement" and a "Reciprocal Defence Procurement Agreement" that will expedite the supply of defence goods in the event of potential supply chain disruptions.

Operationalising India-USA MSRAs

The United States Secretary for the Navy, Mr Carlos Del Toro, has made the deepening of US-India relationship a top priority. Towards this end, the US is advancing its cooperation with India in a number of cutting-edge technological initiatives as part of its *"new maritime statecraft"* policy.[32] It is in clearly in India's current national interest to leverage its ties with the US across multiple domains, with ship-repair constituting an important element of the bilateral maritime partnership. While the servicing and repair of the US Navy's auxiliary vessels (which carry the prefix "USNS") has enabled India to project its state-of-the-art ship repairs facilities, India can consolidate its position as a ship-repair hub in the Indo-Pacific by engaging in the Maintenance, Repair and Overhaul (MRO) of US surface combatants (carrying the prefix "USS") as well. Apprehensions that this might, in the event of a military conflict between the US and the People's Republic of China (PRC), cause the latter to regard India as a belligerent because it is providing direct support to the US war effort are unlikely to be realised. Indeed, this might well be a case of first creating ghosts and thereafter becoming terrified of them! For one thing, the PRC is already engaged in a protracted military stand-off with India that has been punctuated by actual armed action leading to military casualties and fatalities and, in that regard, the PRC already perceives India as a belligerent. For another, if the mere act of shipbuilding or ship-repair support were to be viewed by the PRC as specifically belligerent acts, the number of countries that the PRC would need to address militarily would become too large for such an action to be tenable. Hence, the clear and evident advantages for India significantly outweigh any feelings of vague disquiet that might be projected to the country's politico-military and security establishments.

Consequently, the following steps are recommended:

- The Government of India (MoD, MEA, and MoPSW) need to jointly leverage frameworks such as the "India-US 2+2 Dialogue" to advance Indian PSU and privately owned shipyards to the next step in establishing themselves as regional options-of-choice for MRO activities related to US naval combatant warships, by utilising the legal provisions of Title 10 of the US Code Section 8680.

- Indian shipyards need to be encouraged to conform to US Naval policy and meet prerequisites such as allowing site inspections, the setting-up of specialised MRO departments within the shipyard, and the hiring of technical experts offering MRO solutions, including technology transfers and technical support services.

- The Indian Navy, which aspires to be the "preferred security partner" in the western segment of the Indo-Pacific, namely, the Indian Ocean, is fully aware that 'strategic sealift' has emerged as a major naval function along with 'sea control', 'sea denial', 'power projection', and 'strategic deterrence'. India's senior naval leadership is acutely conscious that the US Navy owns a large reserve of transport ships under the aegis of the Military Sealift Command, which includes fast sealift ships, propositioned stocks, and specialised tanker and container ships.[33] Given that some 50-70 naval ships and submarines are estimated to be forward deployed in the Indo-Pacific,[34] Indian shipyards have a real opportunity of undertaking maintenance, repair, and overhaul (MRO), providing that the restrictions of Section 8680 are waived. Thus, it is the Indian Navy that needs to champion the case for the proliferation of MSRAs amongst Indian shipyards within both, the private and the public sectors.

- The MEA and the MoPSW, too, need to weigh-in and work in a closely coordinated manner so as to enable this opportunity to be properly seized, Since India was able to secure a "clean waiver" from the Nuclear Suppliers' Group (NSG) through US assistance in 2008 (the fact that this was nullified in 2011 notwithstanding) and was able to escape sanctions under the "Countering America's Adversaries Through Sanctions Act" (CAATSA) in 2017 despite its acquisition of Russian S-400 defence systems,[35] it ought to be possible for India to obtain the good offices of the US Secretary for the Navy for repairs of US Navy combatant warship as well, especially at a time when the India-US defence partnership is on the rise, with the US having declared, in 2016, that India was a "Major Defence Partner" (MDP).

- If one were to push the envelope of the MSRA — as a concept — one could reasonably conclude that it need not be limited to solely an India-US construct. The tantalising question then, is whether the MSRA — as a 'concept' rather than simply as a tool in the India-US bilateral toolbox — could be used to have ships of other "distant-water deployers" repaired in Indian shipyards. This might include European navies and could just as easily include the Russian Navy. For instance, India is reportedly keen to sign a LEMOA-like "Reciprocal Exchange of Logistics Agreement" (RELOS) agreement with Russia. Should this be followed up with an MSRA? On the one hand, this might well derail the gains made from the extant India-US MRSAs. On the other, should India desire to assert its strategic autonomy, this might well afford New Delhi a viable pathway.[36] It is recommended that these options be given serious consideration by Indian policymakers as well as policy-shapers.

- It is further recommended that Indian policymakers (the MEA and MoD) and practitioners (basically the Indian Navy) give careful thought to whether MSRAs could be signed for ***Indian*** warships to be repaired in ports other than those in India. Given the increasing appreciation of the importance to India of the Pacific (190 billion US dollars-worth of Indian merchandise trade passes through the South China Sea every year — this figure excludes the value of India's merchandise trade with Indonesia, Malaysia, Thailand, and Singapore) and the robustness of India's responses to China's aggressiveness and Beijing's own fairly ham-handed attempts at bullying New Delhi, it is certain that over the course of the foreseeable future, the Indian Navy's deployments to the western Pacific will increase in both frequency and duration. Consequently, it would be advantageous for the Indian Navy or the MoD to conclude an Indian variant of an MRA with capable repair-yards in, say, Singapore and/or Vietnam and/or Japan and/or South Korea.

Conclusion

To conclude, India is already establishing herself as a major ship-repair hub and the Master Ship Repair Agreements (MSRAs) signed by the US Navy with various Indian shipyards have served to reinforce this national 'brand positioning'. These MSRAs also enhance maritime cooperation in the region while providing Indian shipyards with necessary exposure and opportunities to enhance their enduring ship repair capabilities. However, for India to fully operationalise ship repair agreements to accrue commercial benefits from them, India will have to assess and work around relevant US legislation, thereby bringing more business to Indian shipyards. In addition, India would also be well advised to formulate its own version of MSRAs with different regional players within the Indo-Pacific. Finally, India will need to engage in capacity building and capability enhancement to project herself as a lucrative logistics and ship repairs hub in the Indo-Pacific.

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ENDNOTES

1 US Consulate Chennai, "United States Navy Ship Salvor Reaches L&T Kattupalli Shipyard for Voyage Repairs", 10 July 2023. https://in.usembassy.gov/united-states-navy-ship-salvor-reaches-lt-kattupalli-shipyard-for-voyage-repairs/#:~:text=United%20States%20Navy%20Ship%20Salvor%20Reaches%20L%26T%20Kattupalli%20Shipyard%20for%20Voyage%20Repairs,-Home%20%7C%20News%20%26%20Events&text=Chennai%2C%20July%2010%3A%20Military%20Sealift,on%20Sunday%2C%20July%209%2C%202023

2 Amit Mudgill, "Mazagon Dock Shares in News on Signing MSRA with US Government", *Business Today,* 08 September 2023. https://www.businesstoday.in/markets/company-stock/

story/mazagon-dock-shares-in-news-on-signing-msra-with-us-government-key-details-397395-2023-09-08

3 Doordarshan News, "Cochin Shipyard Signs Master Ship Repair Agreement with US Navy", 06 April 2024. https://ddnews.gov.in/en/cochin-shipyard-signs-master-ship-repair-agreement-with-us-navy/.

See Also, Cochin Shipyards Limited, "CSL sings Master Ship Repair Agreement with US Navy", 06 Aril 2024. https://www.bseindia.com/xml-data/corpfiling/AttachLive/27902f27-05fb-4e35-bf57-cf4c09ea7eed.pdf

4 The "Transportation Command" itself is one of the USA's eleven "unified combatant commands" (COCOMs) — seven of which are "geographic" commands (viz., Africa Command [AFRICOM], Central Command [CENTCOM], Indo-Pacific Command [INDOPACOM], Europe Command [EUCOM], Northern Command [NORCOM], Southern Command [SOUTHCOM]), while the remaining four are "functional" commands (Space Command, Special Forces Command, Strategic Command, and the Transportation Command). See, "Military Units: Navy", US Department of Defense official website. https://www.defense.gov/Multimedia/Experience/Military-Units/Navy/#894.5937805175781

5 The nine component commands of the US Navy are: (1) Fleet Forces Command, (2) Military Sealift Command, (3) Naval Forces Central Command, (4) Pacific Fleet, (5) Naval Special Warfare Command, (6) Fleet Cyber Command/10th Fleet, (7) Naval Forces Europe/ Naval Forces Africa, (8) Naval Forces Southern Command/ 4th Fleet, (9) Operational Test and Evaluation Force. See, *Ibid*.

6 The seven numbered fleets of the US, each of which is commanded by a Vice Admiral, are: (1) the 2nd Fleet, which supports the Fleet Forces Command [the naval component of NORCOM); (2) the 3rd Fleet, which supports the Pacific Fleet Component of the INDO-PACOM and concentrates upon the northern, eastern, and southern Pacific as well as the East Coast of the US; (3) the 7th Fleet, which also supports the Pacific Fleet Component of the INDO-PACOM but concentrates upon the western Pacific; (4) the 5th Fleet, which supports the Naval Forces Central Command component of CENTCOM; (5) the 4th Fleet which supports the Naval Forces Southern Command component of SOUTHCOM; (6) the 6th Fleet, which supports the Naval Forces Europe/Africa Component of EUCOM; and the 10th Fleet, which supports the Fleet Cyber Command component of CYBERCOM, which is itself a sub-Unified Command of the US Strategic Command.(STRATCOM). See, Military Sealift Command Handbook, 2023. https://www.msc.usff.navy.mil/Portals/43/Publications/Handbook/MSCHandbook2023-Final.pdf

7 The White House, "Fact Sheet: Republic of India Official State Visit to the United States", 22 June 2023. https://www.whitehouse.gov/briefing-room/statements-releases/2023/06/22/fact-sheet-republic-of-india-official-state-visit-to-the-united-states/

8 US Consulate General Chennai, "Larsen and Toubro (L&T) Master Ship Repair Agreement Ceremony", 10 July 2023. https://in.usembassy.gov/wp-content/uploads/sites/71/CG-Judith-Ravin-remarks-LT-Master-Ship-Repair-Agreement-Ceremony-final.pdf

9 Anuttama Banerji, "A Contemporary Assessment of the Maritime Impact of the India-US Foundational Agreements", *National Maritime Foundation*, 24 April 2024. https://maritimeindia.org/a-contemporary-assessment-of-the-maritime-impact-of-the-india-us-foundational-agreements/

10 "US CODE-2022, Title 10, Subtitle C, Part IV, Chapter 863, Section 8680". https://www.govinfo.gov/content/pkg/USCODE-2022-title10/pdf/USCODE-2022-title10-subtitleC-partIV-chap863-sec8680.pdf

11 "Voyage Repairs" include: (1) Corrective maintenance on mission or safety essential items necessary for a ship to deploy, to continue on its deployment, or to comply with regulatory requirements. (2) Scheduled maintenance, only to the extent that said maintenance is absolutely necessary to ensure machinery and equipment operational reliability (e.g., diesel top end overhaul) or to comply with regulatory requirements. (3) Voyage repairs do not include corrective maintenance actions that may be deferred until the next scheduled regular overhaul and drydocking availability in the United States or Guam without degrading operational readiness, the environment, habitability standards or personnel safety, or adversely impacting regulatory compliance. See, Samuel Nichols, "Overhaul, Repair and Maintenance of MSC Vessels in Foreign Shipyards". https://silo.tips/queue/subj-overhaul-repair-and-maintenance-of-msc-vessels-in-foreign-shipyards?&queue_id=-1&v=1719222991&u=MTIwLjU3LjcyLjEyMw==

12 Shantanu Chakrabarti, "Nation Branding in Non-Western societies: Projecting India as a 'Civilization State'", *Indian Council for World Affairs* (ICWA), Knowledge World Publishers Pvt Ltd, New Delhi, 2024

13 Keith Lynn Marchbanks, "Ships Maintenance, Repair and Modernisation Overseas: Requirement Concepts and Funding Issues in Maintaining Material Readiness of Deployed Forces", *Calhoun Institutional Archive of the Naval Postgraduate School*, December 1992. https://core.ac.uk/download/pdf/36717217.pdf

14 US Navy Military Sealift Command, "Industry Day 2023: Navy Supply Systems: Yasuka" 26 July 2023. https://www.msc.usff.navy.mil/Portals/43/Business/IndustryDay2023/MSC%20-%20FLCY%20Industry%20Day_KP%20-%20Eng%20and%20Korean.pdf?ver=sIc1SqNCvDJOAqON-awg0Q%3D%3D

15 Decision of the Comptroller General of the United States, "B-187062: Fairburn Marine Aviation", *Government Accountability Office* (GAO), 22 December 1976. https://www.gao.gov/assets/b-187062.pdf

16 US Government, "Subpart 217.71: Master Agreement for Repair and Alteration of Vessels", 2024. https://www.acquisition.gov/dfars/subpart-217.71-master-agreement-repair-and-alteration-vessels

17 Decision of the Comptroller General of the United States, "B-187062: Fairburn Marine Aviation", *Government Accountability Office (GAO)*, 22 December 1976. https://www.gao.gov/assets/b-187062.pdf

18 Press Information Bureau, "Reciprocal Agreement", Ministry of Defence, 04 August 2023. https://pib.gov.in/PressReleasePage.aspx?PRID=1945713

19 Bruce Thornton, "Prestige as a Tool of Foreign Policy", Hoover Institution, 12 June 2017. https://www.hoover.org/research/prestige-tool-foreign-policy

20 Gilpin, Robert. . War and Change in World Politics. Cambridge: Cambridge University Press, (1981) 31.

21 India stands as the second-largest player in the ship-recycling industry behind Bangladesh. The focal point of India's ship recycling prowess is the Alang-Sosiya Ship Recycling Yard (ASSRY) in Gujarat, a coastal stretch in Bhavnagar district. See, Ayushi Srivastava and Commodore Debesh Lahiri, "*Sustainable Recycling in India- Social*, Technological and Environmental Analysis", National Maritime Foundation, 20 February 2024. https://maritimeindia.org/sustainable-ship-recycling-in-india-social-technological-and-environmental-analysis/

22 Dr Vijay Sakhuja, "India: An Emerging Naval-Maritime Maintenance, Repair and Overhaul Destination", *DefStrat*, 22 March 2024. https://www.defstrat.com/magazine_articles/india-an-emerging-naval-maritime-maintenance-repair-and-overhaul-destination/

23 Admiral Karambir Singh and Commander Y Hemanth Kumar, "Combing Shipyards: Strategic Merger of PSU Shipyards for a Stronger Economy", in Vice Admiral Pradeep Chauhan et al eds. *Maritime Perspectives 2023* (New Delhi: National Maritime Foundation, 2023)

24 Banerji, "India-US Foundational Agreements", April 2024.

25 CNBC, L&T signs Master Ship Repair Agreement with US Navy, enhancing Indo-US defence relationship", https://www.cnbctv18.com/business/companies/larsen-and-toubro-signs-master-ship-repair-agreement-with-u-s-navy-17180511.htm

26 Ashish Dangwal, "US Navy Eyes Indian, Japanese and Korean Shipyards to quickly repair its warships during war with China", *The Eurasian Times*, 03 May 2024. https://www.eurasiantimes.com/us-navy-eyes-indian-japanese-korean-shipyards/

27 USNI News, "Indian to take on Future US Navy Ship Maintenance per Agreement", 14 September 2023. https://news.usni.org/2023/09/14/india-to-take-on-future-u-s-navy-ship-maintenance-per-agreement

28 Gill Barnodollar and Matthew C. Mai, “The US Navy Can’t Build Ships”, *Foreign Policy*, 17 May 2024. https://foreignpolicy.com/2024/05/17/us-navy-ships-shipbuilding-fleet-china-naval-race-pacific/

29 Damien Cave, “US Pursues Defence Partnership with India to Deter Chinese Aggression”, *The New York Times,* 17 October 2023. https://www.nytimes.com/2023/10/17/world/asia/india-us-defense.html

30 US Consulate Chennai, “United States Naval Ship Matthew Perry Returns to Indo-Pacific Waters After Voyage Repair in India”, 28 March 2023. https://in.usembassy.gov/united-states-naval-ship-matthew-perry-returns-to-indo-pacific-waters-after-voyage-repair-in-india/

31 US Consulate Chennai, United States Navy Ship Salvor Reaches L&T Kattupalli Shipyard For Voyage Repairs”, 10 July 2023. https://in.usembassy.gov/united-states-navy-ship-salvor-reaches-lt-kattupalli-shipyard-for-voyage-repairs/

32 US Navy, “SECNAV Delivers Remarks at Harvard Kennedy School”, 26 September 2023. https://www.navy.mil/Press-Office/Speeches/display-speeches/Article/3538420/secnav-delivers-remarks-at-harvard-kennedy-school/

Also see, Stimson Center, “Maritime Power for Global Security: A Conversation with US Navy secretary Carlos Del Toro”, 23 April 2024. https://www.stimson.org/event/maritime-power-for-global-security-a-conversation-with-u-s-navy-secretary-carlos-del-toro/

33 Loyola, “Jones Act” 2020, 16

34 Commander, US 7th Fleet, “The United States Seventh Fleet”, https://www.c7f.navy.mil/About-Us/Facts-Sheet/

35 Times Now, “CAATSA waiver for India approved: What is CAATSA and the move is more beneficial for US than India”, *Times Now*, 15 July 2022. https://www.timesnownews.com/explainer/caatsa-waiver-for-india-approved-what-is-caatsa-and-why-the-move-is-more-beneficial-for-the-us-than-india-article-92897329

36 Rajeshwari Pillai Rajagopalan, “India’s Military Outreach: Military Logistics Agreements”, *The Diplomat,* 09 September 2021. https://thediplomat.com/2021/09/indias-military-outreach-military-logistics-agreements/

Ballast-Water Management Alternatives Offered by Ballast-Free Shipping (Part 1)

Ms Ayushi Srivastava

The use of water as ballast in steel-hulled vessels has been a fundamental aspect of maritime operations, ensuring that ships maintain stability, manoeuvrability, and safety as they navigate the world's oceans. This practice involves the periodic intake and pumping-out of seawater into ships' ballast tanks to counterbalance weight changes due to variations in cargo load, fuel, and water consumption. While indispensable for the safe and efficient functioning of modern shipping, the ballasting process inadvertently serves as a conduit for the global translocation of a myriad of marine micro-organisms, ranging from microscopic bacteria and microbes to small invertebrates, eggs, cysts, and larvae of various species. As ships discharge ballast water in new ports, they can (and do) introduce non-native species into foreign ecosystems, where they may thrive, out-compete indigenous species, and precipitate ecological and economic disruptions.[1]

The ecological ramifications of ballast water-mediated bio-invasions first came to light following the mass occurrence of the Asian phytoplankton algae Odontella (*Biddulphia Sinensis*) in the North Sea in 1903, marking a pivotal moment in human understanding of these phenomena. However, it was not until the 1970s that the scientific community began to systematically address the issue, with significant concerns being raised by the late 1980s, particularly by countries such as Canada and Australia, which were directly affected by invasive species. These concerns were escalated to the International Maritime Organization's "Marine Environment Protection Committee" (MEPC), emphasising the growing international alarm over the issue. Despite increased awareness and regulatory efforts, the problem of invasive species, facilitated by the burgeoning volumes of seaborne trade, continues to escalate, threatening biodiversity and human health in newly invaded areas. This ongoing crisis highlights the urgent need for innovative solutions, such as ballast-free vessels, to prevent further ecological damage while maintaining the global shipping industry's operational requirements.[2]

Invasive Species and Ballast Water

The expansion of non-indigenous species beyond their natural habitats is driven by the increased movement of goods and people, which is itself facilitated by increasing globalization. This results in the inadvertent introduction of "non-indigenous aquatic species" (NIASs) into new environments through human activities. Some of these NIASs can establish populations that spread, posing potential risks to ecosystem integrity, biodiversity, socio-economic values, and human health. These invasive species, also generically referred-to as "harmful aquatic organisms and pathogens" (HAOPs), are widely acknowledged for the significant threat that they pose to biodiversity and economic interests. HAOPs possess the ability to disrupt ecosystem processes, devalue water resources for human use, and trigger various socio-economic repercussions. Consequently, the global management of HAOPs is critical, especially considering the escalating trends in global trade, which amplify the risks associated with the spread of these organisms.[3]

Invasive species pose a significant threat to the conservation and sustainable utilisation of global, regional, and local biodiversity, exerting considerable adverse impacts on the ecosystem services provided by natural habitats. This trend is rapidly breaching biogeographic barriers critical for the maintenance of global biodiversity, leading to increased homogenisation. The Convention on Biological Diversity (CBD) underscores the urgent need to identify and prioritise invasive alien species and pathways by 2020, with targeted efforts to control or eradicate priority species and implement measures to manage pathways, thereby preventing their introduction and establishment. For instance, in India's historical context, the introduction of English Trout (*Salmo Trutta Fario Linnaeus*) in 1863 marked the beginning of a series of introductions of various alien species into the country's aquatic ecosystems. This has culminated in a diverse array of alien species, enriching India's aquatic resources but also necessitating vigilant management strategies.[4]

Ballast water serves as a critical element in ensuring the safe operation of ships by facilitating stability and manoeuvrability. Historically, solid materials like rocks and sand were used. However, the adoption of water as ballast material became prevalent due to its convenience and accessibility. Annually, approximately 10 billion tons of ballast water are discharged globally. Nevertheless, the discharge of untreated ballast water poses significant environmental and economic risks as sediment and various organisms, including bacteria, microbes, and larvae, are carried within it.[5] Upon discharge, these organisms may thrive in new environments, potentially becoming invasive species. Consequently, ballast water discharge from ships on international voyages has caused the invasion of alien organisms and has been listed as one of the four major hazards of the ocean by the Global Environmental Protection Fund (GEF).[6]

The introduction of invasive species through ballast water discharge has led to substantial ecological and economic damage worldwide. Notable examples include the zebra mussel invasion in the Great Lakes and the introduction of the European Green Crab to Canadian waters.[7] These invasions disrupt local ecosystems, damage infrastructure, and incur considerable cleanup and repair costs.[8]

Ballast Water Management (BWM)

To address the risks associated with ballast water discharge, stringent regulations and management protocols have been implemented globally. For instance, Canada enacted "Ballast Water Regulations" under the Canada Shipping Act, 2001, and ratified the International Maritime Organization's Ballast Water Management Convention (BWMC). These regulations mandate the installation of ballast water management systems on ships and adherence to specific standards for ballast water treatment and discharge.[9]

BWM plans play a pivotal role in ensuring compliance with regulations. These plans delineate procedures for the safe management of ballast water and necessitate record-keeping to monitor ballast water exchange and treatment. BWM systems utilise diverse technologies such as filters, chemicals, and ultraviolet light to eradicate harmful organisms from ballast water before discharge. Through a comprehensive two-stage treatment process, solid particles are removed, and potentially harmful marine organisms are destroyed, effectively mitigating the spread of invasive species, and safeguarding marine ecosystems and economies.

"The International Convention for the Control and Management of Ships' Ballast Water and Sediments", which was adopted on 13 February 2004 and entered into force on 08 September 2017, mandates that all vessels engaged in international traffic adhere to specific standards for managing their ballast water and sediments, as stipulated in a vessel-specific ballast water management plan. Additionally, every vessel requires to carry a 'ballast water record book' and an 'international ballast water management certificate'. Thus, all new-build vessels will need to incorporate an on-board ballast water treatment system, while existing vessels will need to have one retrofitted on board. As an interim measure, however, vessels are permitted to conduct mid-ocean "ballast water exchanges", denoting the flushing-through of their ballast tanks multiple times in deep water and at distances well removed from the coast. The International Maritime Organization (IMO) outlines two primary standards:[10]

1. "D1 Standard". The "D1 Standard" involves a process called Ballast Water Exchange (BWE), where ships are required to achieve a minimum of 95% volumetric exchange of ballast water. This means that at least 95% of the ballast water on board needs to be replaced. Achieving this efficiency involves a method called ***'pumping through'***, which requires the ship to pump out and replace the ballast water three times in succession. Moreover, for this operation to be considered compliant, it must occur at least 200 nautical miles away from the shore, and the water depth should be a minimum of 200 metres. While there is some relaxation available for the distance from shore at which compliant 'pumping through' needs to occur (a minimum distance of 50 nautical miles appears to be acceptable), there is no relaxation to the minimum depth (which must be 200 metres or more). This notwithstanding, vessels are nevertheless required to communicate with Port State authorities to understand any specific requirements for BWE in local waters.[11]

2. "D2 Standard". The "D2 Standard" (as amended by the 72nd session of the Marine Environment Protection Committee [MEPC 72]) focuses upon the performance of ballast water in terms of its chemical composition and the presence of organisms. To comply with the D2 standard, ships need to obtain a report from an accredited laboratory, confirming compliance with D2 Ballast Water Performance Testing. The aim of this standard is to establish acceptable levels of organisms present in discharged ballast water. The acceptable levels include:

   - Discharge fewer than 10 viable organisms per cubic metre, with dimensions equal to or greater than 50 micrometres, and fewer than 10 viable organisms per millilitre, with dimensions less than 50 micrometres but equal to or greater than 10 micrometres.
   - Additionally, the discharge of indicator microbes, as a human health standard, must not exceed specified concentrations.[1]

Figure 1. IMO Ballast Water Management Convention

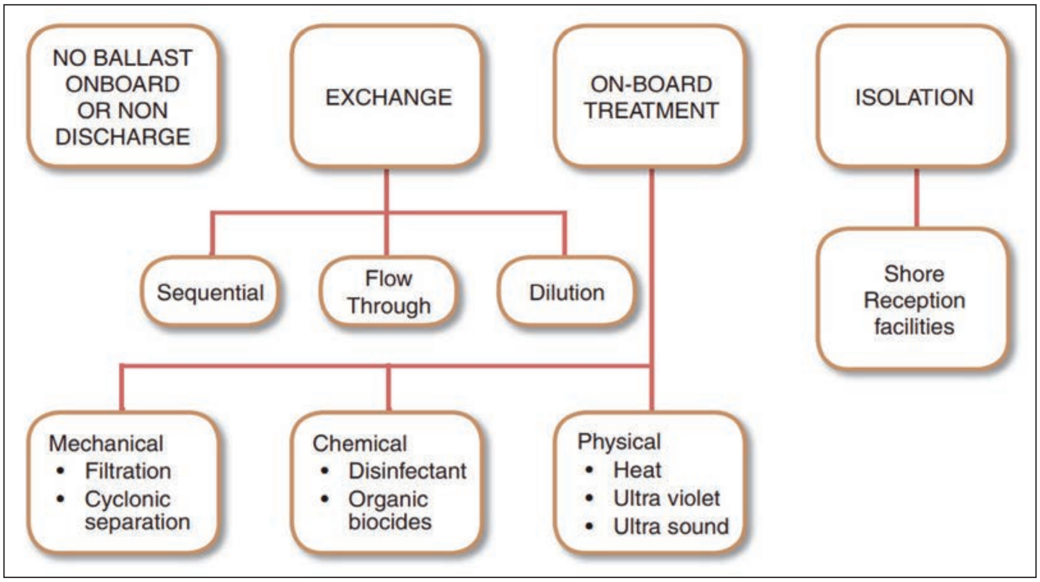
Source: International Maritime Organisation

Shipowners and business managers primarily depend on various ballast water treatment technologies, including heating, electrolysis, and UV treatment, to ensure compliance with regulations. However, there are challenges to be faced. These technologies not only consume significant time and labour but also escalate operational expenses for shipowners and operators. As a result, while addressing the pressing issue of the spread of invasive species, the implementation of ballast water treatment technologies necessitates a careful balance to be struck between regulatory compliance and the economic sustainability of maritime operations.[13] The Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) has recognised that "*the emission of [chlorination related] chemicals coming from ballast water management systems is a rather new potential threat to marine environment*". Consequently, within the framework of the procedure for approval of ballast water management systems utilising active substances (G9), the GESAMP Ballast Water Working Group is actively engaged in assessing systems employing active substances. During this assessment, various models are being applied and tested to evaluate the impact of residual chemicals present in ballast water discharges.[14] Both BWE and Ballast Water Management Systems (BWMS) necessitate the utilisation of robust equipment, leading to the substantial consumption of electricity. This heightened demand for electrical power, in turn, escalates the consumption of heavy fuel oil (HFO) and leads to the additional emissions of pollutants into the atmosphere.[15] Additionally, Class NK has observed several common problems associated with BWMS. These include malfunctions in highly turbid waters, issues with BWMS-related parts, limited lifespan of consumables, and clogging of the 'total residual 'oxidants samplingline. Addressing these challenges is essential for ensuring the effective implementation and operation of BWMS to mitigate the spread of invasive species in marine environments.[16]

Innovations in Ship Design

The conventional practice of configuring ballast tanks, mainly aimed at enhancing navigational safety and stabilising ships during light loads, has been reevaluated. This reassessment has led to the possibility of innovation in ship design to achieve a higher centre of buoyancy while lowering the centre of gravity, thereby making the ship stable in varying conditions of loading. One such innovation in ship design pertains to the concept of ballast-less tanks (US patent #6694908, 2004), pioneered by Dr Michel Parsons of the University of Michigan, USA. Dr Parsons presented his groundbreaking findings at the annual meeting of the American Society of Shipbuilding and Marine Engineering in 2004, focusing on the design of non-ballasted tanks and the specifics of through-flow system hull technology.[17]

Figure 2. Ballast Water Management Options



Source: GloBallast Partnerships

Another innovative ship-design has been propounded by the Shipbuilding Research Centre of Japan (SRC) which, in 2003, introduced a concept known as the 'storm ballast ship', primarily for tankers. This entails a V-shaped hull form with optimised buoyancy distribution. By altering the vertical distribution of hull buoyancy and widening the beam, this design ensures a deeper draught even in light conditions, thereby maintaining stability. The incorporation of a V-shape cross-section minimises the need for ballast water exchange, thereby reducing the risk of introducing invasive species.[18]

Yet another significant innovation is the 'Flow System Hull' which replaces the longitudinal structure below the cargo waterline with a pressurised water tank system. This design feature converts the original closed system to a front and rear open configuration, allowing seawater to flow continuously from the bow inlet to the stern outlet. This flow-through mechanism effectively minimises or eliminates altogether the need for static ballast water tanks. Moreover, the design complies with IMO regulations on marine environmental protection by utilising local seawater and avoiding the transfer of seawater between locations.[19]

Researchers at the University of Michigan have conducted extensive tests on vessels equipped with the "Flow System Hull". The results demonstrate that these ships maintain stability while utilising seawater flow to additionally enhance propulsion efficiency. With seawater flowing from the front to the rear through large pipes installed at the bottom of the ship, the propeller can accelerate rotation, increase speed, and significantly reduce fuel consumption and emissions. Test results indicate potential fuel savings of up to 7.3%, highlighting the efficiency and environmental benefits of innovative ship design approaches in addressing bio-invasion risks associated with ballast water exchange.[20]

There are clearly exciting times ahead as ship designers attempt to offer alternatives to the standard methods and processes of ballast water management. The central question, of course, is whether the various alternatives being offered by a growing number of ship design firms will in fact be economically viable or whether they will be mere curiosities for history to smile at. Here, as indeed, in every other innovation, the devil lies in the details. It is these details that Part 2 of this article will address.

To be continued in Part 2…

16 April 2024

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ENDNOTES

1 "Ballast Water Management", International Maritime Organisation https://www.imo.org/en/ourwork/environment/pages/ballastwatermanagement.aspx

2 *Ibid*

3 Yung-Sheng Chen, Kang Chao-Kai, and Liu Ta-Kang, "Ballast Water Management Strategy to Reduce the Impact of Introductions by Utilizing an Empirical Risk Model" *Water 14*, No 6: 981, 2022, https://doi.org/10.3390/w14060981

4 Ramakrishna, "Bio-invasion of Aquatic Invasive Species in India", in *Invasive Alien Species: Observations and Issues from Around the World* eds T Pullaiah and Michael R Ielmini, (John Wiley & Sons Ltd., 2021), Volume 2, 38-72

5 P Ramani and V Sasirekha, "Management of Ballast Water - Ballast Free Shipping - The Way Forward", *AMET International Journal of Management*, ISSN 2231-6779, June 2014. https://www.researchgate.net/publication/269876003_Management_Of_Ballast_Water_-_Ballast_Free_Shipping_-_The_Way_Forward?enrichId=rgreq-3668a29f7262aca4acc18d3dde7f3424-XXX&enrichSource=Y292ZXJQYWdlOzI2OTg3NjAwMztBUzo3NzE5MDAzNzY2MjUxNTNAMTU2MTA0Njc5OTA0MA%3D%3D&el=1_x_3&_esc=publicationCoverPdf

6 Wang Hong and Li Huabin, "Comment on Ballast Free Ship", *International Journal of Engineering and Applied Sciences (IJEAS) ISSN*: 2394-3661, Volume-5, Issue-12, December 2018 Comment on Ballast Free Ship (researchgate.net)

7 Markus Frederich and Emily R Lancaster, "The European Green Crab, *Carcinus Maenas*: Where did they Come from and Why are they Here?", in *Ecophysiology of the European Green Crab (Carcinus Maenas) and Related Species*, eds Dirk Weihrauch and Iain J McGaw, United States: Academic Press, 2024, 1-20

See Also: The European green crab, Carcinus maenas: Where did they come from and why are they here? - ScienceDirect

8 "Ballast Water Management", International Maritime Organization, https://www.imo.org/en/ourwork/environment/pages/ballastwatermanagement.aspx

9 “Ballast Water Regulations,” Transport Canada, Government of Canada, Ballast Water Regulations - Canada.ca

10 “Ballast Water Management Convention Aims to Stop the Spread of Potentially Invasive Aquatic Species in Ships’ Ballast Water”, International Maritime Organisation, 08 September 2017. https://www.imo.org/en/MediaCentre/PressBriefings/Pages/21-BWM-EIF.aspx

11 International Convention for the Control and Management of Ships’ Ballast Water and Sediments (BWM), International Maritime Organisation, https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Control-and-Management-of-Ships%27-Ballast-Water-and-Sediments-(BWM).aspx

12 *Ibid*

13 Wang Hong and Li Huabin, “Comment on Ballast Free Ship”, *International Journal of Engineering and Applied Sciences (IJEAS)*. 5. 10.31873/IJEAS.5.12.05

14 Ballast Water Working Group, Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), http://www.gesamp.org/work/groups/34

15 Identifying and Managing Risks from Organisms Carried in Ships’ Ballast Water, *GloBallast Monograph Series Nov 21,* GloBallast Partnerships Project Coordination Unit, International Maritime Organization and World Maritime University (WMU), 2013, https://wwwcdn.imo.org/localresources/en/OurWork/PartnershipsProjects/Documents/Mono21_english.pdf

16 Ballast Water Management Convention, Class NK, https://www.classnk.or.jp/hp/en/activities/statutory/ballastwater/index.html

17 Michael G Parsons, Miltiadis Kotinis, Thomas Lamb, and Ana Sirviente, “Development and Investigation of the Ballast-Free Ship Concept”, *Transactions of SNAME*, Vol 112 (2004): 206-240, https://www.researchgate.net/publication/289047828_Development_and_investigation_of_the_ballast-free_ship_concept?enrichId=rgreq-0d1db4085aa18c904b19e7c188eeac31-XXX&enrichSource=Y292ZXJQYWdlOzI4OTA0NzgyODtBUzo0MzQyMDk5MjkwNzY3MzhAMTQ4MDUzNTEyMjgwNA%3D%3D&el=1_x_2&_esc=publicationCoverPdf

18 Avinash Godey, SC Misra, and OP Sha, “Development of a Ballast Free Ship Design”, *International Journal of Innovative Research & Development,* Vol 1 Issue 10, December 2012

19 Wang Hong and Li Huabin, “Comment on Ballast Free Ship”, International Journal of Engineering and *Applied Sciences (IJEAS)*, DOI: 10.31873/IJEAS.5.12.05

20 *Ibid*

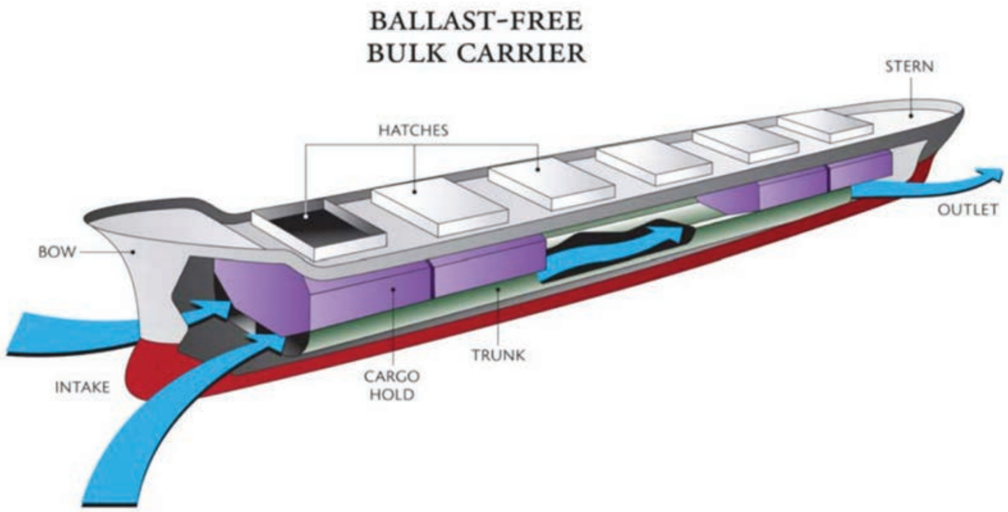
Ballast-Water Management Alternatives Offered by Ballast-Free Shipping (Part 2)

Ms Ayushi Srivastava

The first part of the article examines the critical role of water ballast in maritime operations and its unintended consequence of spreading invasive species globally. It traces the historical context of invasive species introduction through ballast water, highlighting significant ecological and economic damages worldwide. The section also delves into current ballast water management regulations and technologies, emphasising the need for innovative solutions. It concludes by introducing innovative ship designs aimed at mitigating bio-invasion risks associated with ballast water exchange. This part will delve deeper into these innovative designs and explore their potential to revolutionise maritime technology, posing the question of whether they represent a new era in shipbuilding or remain theoretical concepts.

The Ballast-Free Ship (BFS) concept, invented (US Patent #6,694,908, 2004) and initially investigated at the University of Michigan, aimed to minimise the risk of introducing nonindigenous aquatic species into the Great Lakes and other coastal waters by ships arriving in ballast condition.[1] The key features of this ballast-free ship concept included a modified hull design with longitudinal structural ballast trunks or passages, that extend from the bow to the stern of the vessel. These trunks facilitated a continuous flow of local seawater through the ship, rather than storing and transporting a specific volume of ballast water. The pressure difference between the bow and stern of the ship creates a natural flow of water through the trunks, ensuring that any organisms present are discharged within an hour's sailing distance from where they were initially taken on board. This innovative approach effectively eliminates the risk of introducing invasive species by preventing the transportation of ballast water from one location to another. Additionally, the ballast-free design eliminates the need for expensive ballast water treatment equipment, such as filters, ultraviolet irradiation, and chemical biocides, potentially reducing both capital and operational costs.[2]

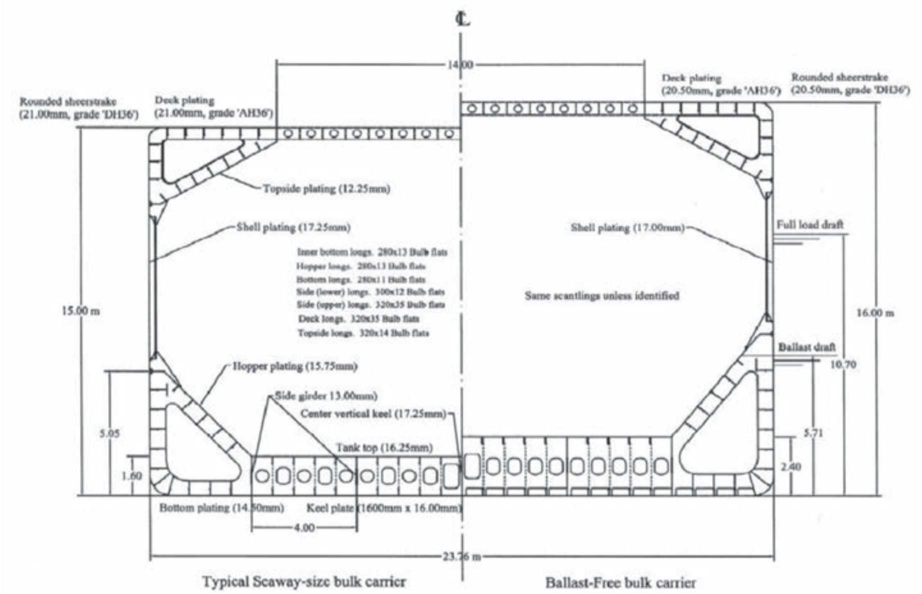
Figure 1. Conceptual Drawing of the Ballast-Free Ship Design



Source: Further Development and Optimization of the Ballast-Free Ship Design Concept, Great Lakes Maritime Research Institute

A schematic of this concept is shown in Figure 1. A comparison between the arrangement of a conventional seaway-size bulk carrier and an equal grain capacity BFS concept seaway-size bulk carrier is presented in Figure 2, with the conventional layout shown on the left and the modified design on the right. In this example, the three ballast trunks per side are connected to the sea via plenums positioned at the bow and stern. These trunks are swamped with seawater to reduce the buoyancy of the vessel in the ballast condition in order to get the vessel down to its ballast drafts. As a ship moves through the water, a natural hydrodynamic pressure differential develops between its bow and stern regions, inducing a slow flow within the open ballast trunks. This mechanism ensures that the ballast trunks are continuously filled with slowly moving "local seawater", preventing the transport of nonindigenous aquatic species globally. Consequently, from a traditional perspective, the vessel becomes effectively "ballast free" in foreign waters.[3]

Figure 2. Midship Section of a typical Seaway-size Bulk Carrier (left) and Ballast-Free Concept Bulk Carrier (right)



Source: Further Development and Optimization of the Ballast-Free Ship Design Concept, Great Lakes Maritime Research Institute

Additionally, an economic comparison was made in 2011 between a ballast free and a conventional seaway-size bulk carrier. It was assumed that ballast water exchange would no longer be permitted, and the conventional bulk carrier would be required to have a ballast water treatment system consisting of an automatic backwash filter followed by UV treatment to meet International Maritime Organisation (IMO) requirements. In this system, UV treatment would be utilised during both intake and discharge. The trade scenario assumed a ballast voyage from Rotterdam to Duluth, MN, at the head of the Great Lakes, to load grain for an 8 m seaway draft return voyage. The greater hull depth, fullness, and hull steel weight of the ballast free bulk carrier were considered. Construction costs were calculated assuming foreign new construction typical of South Korea, using 2011 shipbuilding steel and fuel prices. Since the study of Michael G. Parsons and Miltiadis Kotinis showed no significant change in required propulsion power, no change in required propulsion fuel was included. An updated cost estimate for the capital and operating costs associated with the eliminated filtration/UV treatment system was also provided, based on a

Finnish study,[4] adjusted for inflation up to 2011. The estimate included the closed fore peak tank/aft peak tank trim control system, and the additional trunk fill and empty lines. The net savings for the ballast free bulk carrier with the ballast trunk water discharge close to Station 17[5] were estimated to be about $0.50 per tonne of cargo.[6]

A pivotal consideration for the BFS concept's feasibility was its impact on the vessel's hydrodynamic performance. This aspect was scrutinized through several projects funded by the Great Lakes Maritime Research Institute and supported by the United States Department of Transportation. Investigations were carried out using both towing tank experiments and Computational Fluid Dynamics (CFD) simulations to analyse the interaction between water suction/discharge and the flow around a bulk carrier vessel, including propeller inflow dynamics.[7]

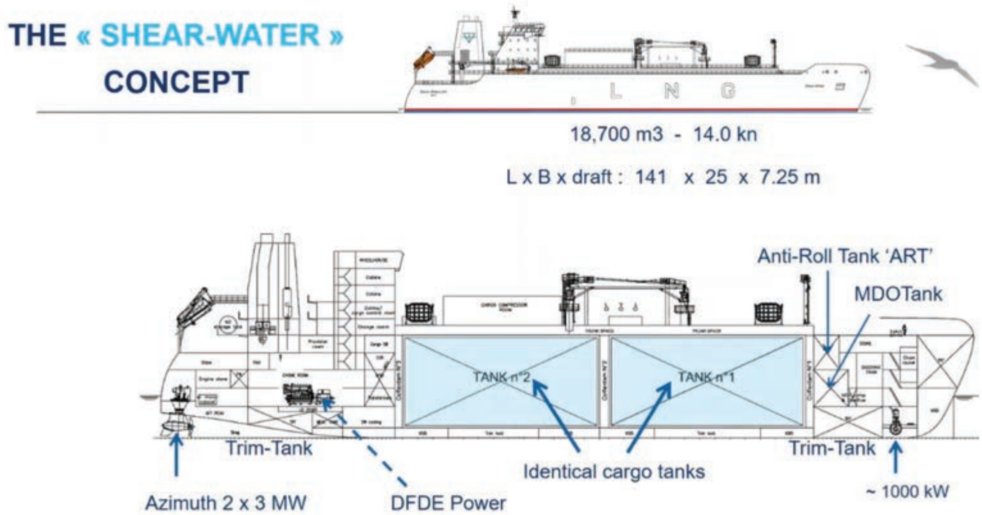
The research indicated that discharging water at the stern at low speeds, relative to the ship's speed, did not adversely affect the vessel's propulsion requirements and could result in approximately 1.6% fuel savings in no load condition. These investigations, conducted at model scale using standard experimental ship hydrodynamic analysis procedures, could not accurately scale viscous flow, thereby limiting the full understanding of flow interactions within the boundary layer.[8]

To overcome this limitation, a revised approach was adopted to quantify the BFS concept's impact on the vessel's flow characteristics. The initial step involved using CFD to analyse the wake of the un-appended vessel for both model and full-scale operations in full load and ballast conditions. The final results showed that the ship not only maintained good stability but also benefited from the seawater flow from front to back through the two large pipes installed at the bottom of the ship. This design allowed the propeller to accelerate the rotation, thereby increasing speed, saving fuel, and reducing emissions.[9]

Case Study: The Shear-Water Project by GTT

Gaztransport & Technigaz (GTT) is a French engineering company specialising in the design and development of containment systems for the maritime transportation and storage of Liquefied Natural Gas (LNG).[10] Recognized for their innovative and efficient solutions in the LNG sector, GTT initiated the Shear-Water Project, which focuses on developing a ballast-free LNG feeder and bunker vessel. This project aims to implement the Ballast-Free Ship (BFS) concept, eliminating the need for conventional ballast water systems and thereby reducing the risk of transporting nonindigenous aquatic species.[11]

Figure 3. Shear-Water Concept for a ballast free LNG Feeder & Bunker Vessel

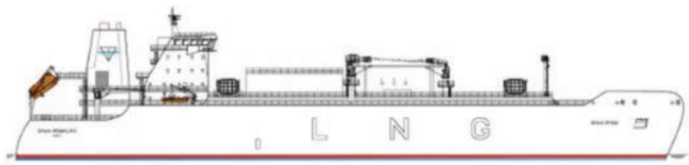


Source: GTT, Hamburg Ship Model Basin (HSVA) and Bureau Veritas, Webinar on "Ballast Water Free LNG Feeder & Bunker Vessel", 08 November 2022

The Shear-Water concept, illustrated in Figure 3,[12] proposed a design for an LNG Feeder & Bunker Vessel of 18,700 m^3 of cargo volume at a design speed of 14 knots. It has a twin-screw azimuth propulsion system,[13] which enhanced manoeuvrability and provides a high-power reserve in harsh conditions when the vessel is empty. Trim management was a critical design consideration for this vessel. A careful longitudinal distribution of weight and buoyancy was achieved through design, and a dedicated trim-water system was provided using permanently onboard fresh water. This allowed the vessel's trim to be managed effectively and in compliance with regulations.

The vessel was designed to maintain zero trim in a fully loaded condition and some aft trim when empty to improve propeller immersion. A bulbous bow shape was deemed unnecessary due to the frequently changing drafts when operating as an LNG bunker vessel. The cargo tanks could be filled at any level without restriction. The operator needed to ensure the vessel's trim remained within the required range—between zero trim and about 1.5 metres aft, or possibly 1 meter forward—and complied with visibility rules. The main dimensions of the vessel could be observed in Figure 4.[14]

Figure 4. Ballast Free LNG Feeder & Bunker Vessel preliminary dimensions and details



Classification for Worldwide operation	
Length overall	141 m
Length between perpendiculars	134.50 m
Breadth, moulded	25.00 m
Depth, at main deck (CL)	17.825 m
Design Draft	7.25 m
Scantling Draft	7.75 m
Empty Draft / Trim	4.2 / 1.7 m
Air Draft (above Empty Draft, abt.)	30 m
Deadweight at design draft	9 600 tons
Cargo Capacity (100%V)	18 700 m³
Boil-Off-Rate (MkIII-Flex)approx.	0.165 %V per day
Speed at design draft, 85% MCR, 20% SM	14.0 kn
Range on 300t MDO, 12.5 kn, at design draft	4 000 nm
Maximum speed, empty	> 16 kn
Diesel-Generating sets	3 x 6L34DF
Total Engine Power installed	3 x 2880 kW = 8640 kW
Electrical Propulsion Motors	2 x 3 000 kW
Azimuth thruster (SRE700 or equivalent)	2 x 3.2 m, FP
Bow Thruster	1000 kW
Accommodation	21-23 persons

Source: GTT, HSVA and Bureau Veritas, Webinar on "Ballast Water Free LNG Feeder & bunker vessel", 08 November 2022

Roll motions were effectively reduced by substantial bilge keels and an Anti-Roll Tank (ART) from Hoppe Marine. The ART, installed in the forward part of the vessel where space was available without cargo loss, was designed for use in empty conditions but could also be used in loaded conditions with somewhat reduced effect. Operation of the ART was optional and utilised onboard trim water, maintaining cargo deadweight.

Key Design Considerations:

- Ballast-Free Approach: The Shear-Water concept eliminates the need for ballast water altogether by utilising a unique hull design. This approach avoids the risks of transferring harmful aquatic organisms and pathogens, as well as the investment and operating costs associated with ballast water treatment systems.
- V-Shaped Hull: The Shear-Water design features a "V-shaped" hull, which differs from the traditional square-shaped mid-ship sections used for LNG carriers. This hull shape is crucial in maintaining sufficient draft for safe navigation, even when the vessel is empty or partially loaded.
- Membrane Tank Design: The Shear-Water concept leverages GTT's expertise in membrane containment systems. The hull lines and the incorporated membrane tanks are designed to fit perfectly, reducing the free surface effects of LNG when the vessel is partially loaded.
- Simplified Operations: The design incorporates two identical cargo tanks to simplify operations. Additionally, an effective ART system is provided in the vessel's forward part to reduce roll motions.
- Improved Efficiency and Emissions: Compared to a conventional vessel, the Shear-Water design offers a power reduction of over 10% due to its lower consumption, leading to reduced emissions.

Comprehensive Testing

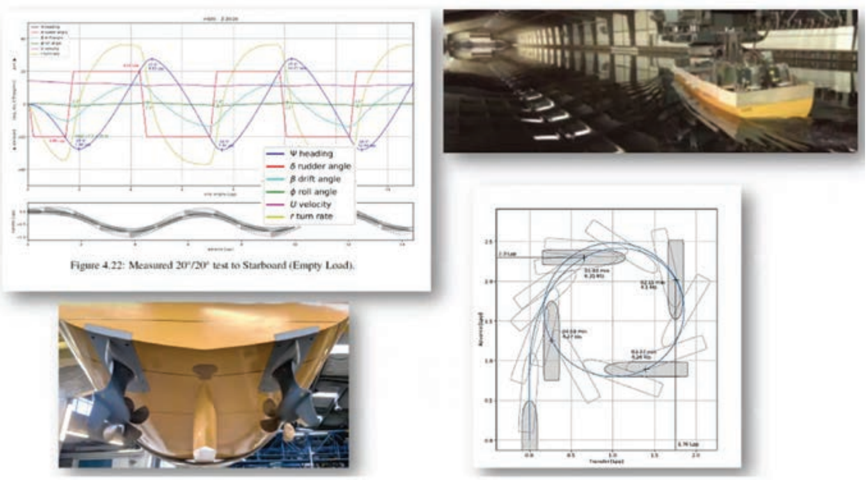
The Shear-Water Project included extensive hydrodynamic tests to ensure the vessel's performance and safety. The tests were conducted with a self-propelled model at a scale of 1:18, measuring 7.75 meters in length and weighing 2.8 tons when laden, as shown in Figure 5. Classical calm water tests, covering speed-power and manoeuvring, demonstrated a power reduction of 10-15% in the speed range of 10-14 knots when averaging values between fully loaded and empty conditions.

Figure 5. Speed- Power Test

Source: GTT, HSVA and Bureau Veritas, Webinar on "Ballast Water Free LNG Feeder & Bunker Vessel", 08 November 2022

Manoeuvring tests, depicted in Figure 6, revealed that the vessel exceeded IMO requirements and expectations, showcasing perfect course-keeping combined with

Figure 6. Manoeuvring Test



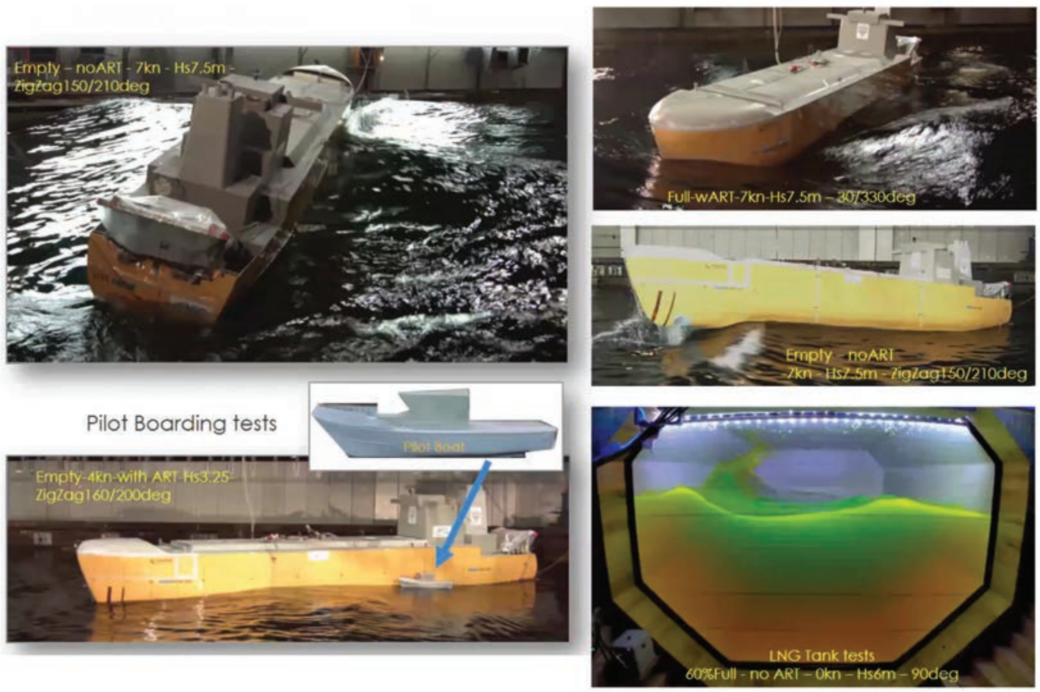
Source: GTT, HSVA and Bureau Veritas, Webinar on "Ballast Water Free LNG Feeder & Bunker Vessel", 08 November 2022

excellent manoeuvring capabilities. These tests are crucial as they evaluate the ship's ability to navigate and control its path under various conditions, ensuring safety and efficiency in operations.

Seakeeping performance tests, conducted in selected sea states up to NATO Sea-State 7 (Hs 7.5m)[15] and illustrated in Figure 7, showed no unusual, excessive, or dangerous behaviour. These tests are essential to assess the vessel's behaviour in rough sea conditions, ensuring it can withstand and operate safely in harsh environments. The tests and investigations covered various aspects, including motions and accelerations, rolling (including parametric excitation), slamming, propeller immersion, green water, and speed loss in waves. The course-keeping ability in waves was considered excellent, and the ship was never found to be out of control.

Further tests were conducted for pilot transfer operations, revealing a roll reduction of about 60% when comparing scenarios with and without the Anti-

Figure 7. Seakeeping Test



Source: GTT, HSVA and Bureau Veritas, Webinar on "Ballast Water Free LNG Feeder & Bunker Vessel", 08 November 2022

Roll Tank (ART). Additional tests with the incorporated LNG tank examined the coupling effects between tank liquid motions and external wave excitation.

A dedicated full sloshing campaign was conducted for worldwide conditions, yielding favourable results with no filling restrictions for the chosen Mark III Flex containment system. These tests are important to ensure the integrity and safety of the LNG containment system under dynamic conditions. The insulation foam density was standard 130 and partially 150 kg/m^3, and the design Boil-Off Rate was 0.165% volume/day.[16]

In summary, the Shear-Water concept underwent rigorous testing and emerged with flying colours in speed-power, manoeuvring, and seakeeping tests, proving its robust design and operational efficiency. These comprehensive tests confirm the vessel's ability to meet stringent performance and safety standards, positioning it as a viable and innovative solution for the maritime industry.[17]

Approved in Principle (AiP)

The Shear-Water concept, has received Approval in Principle (AiP) from leading classification societies, including Bureau Veritas (BV), China Classification Society (CCS), and Det Norske Veritas (DNV).[18] The approval process involved evaluation of key factors such as the design's compliance with the Energy Efficiency Design Index (EEDI)[19] requirements for vessels ordered before 2030.

Granting AiP demonstrates the concept's clear performance and environmental benefits. These benefits include eliminating the need for ballast water treatment systems and equipment, simplifying the maintenance of the void spaces surrounding the cargo, and reducing propulsion power requirements. By addressing these critical aspects, the Shear-Water concept not only enhances operational efficiency but also contributes to environmental sustainability, making it a promising solution for the future of maritime transportation. The strong foundation provided by the AiP ensures that the Shear-Water concept is well-positioned to advance toward full-scale implementation, offering a viable alternative to traditional ballast water management practices.

Advantages of the Shear-Water Concept Over Conventional Vessels:

The Shear-Water concept offers several significant advantages over conventional vessels of similar size. First estimates indicated a cost reduction of about 5% in terms of capital expenditure (Capex), attributed to the absence of a ballast water system (including pumps, valves, pipes, and smaller sea-chests) and the elimination of ballast water treatment systems (BWTS). This design also reduces the need for air vents and sounding pipes control.

Operational expenditure (Opex) is also favourably impacted, with annual reductions estimated at around $100,000 to $200,000. These savings are due to decreased fuel consumption resulting from the power reduction when the vessel is empty, attributed to its smaller displacement. Additionally, there is a reduction in energy consumption due to the lack of a ballast water system, eliminating the need for pump power consumption, consumables, and spares. Maintenance costs are further reduced by the elimination of ballast tank coatings, anodes, paint, and the avoidance of sediment-related maintenance issues. The streamlined design saves considerable time during dry-docking, reducing docking time and associated costs.

From an environmental perspective, the Shear-Water concept represents a substantial improvement. Emissions are reduced by 10-15% compared to conventional vessels, making this design a significant step towards more sustainable maritime operations.[20]

Reasons for Lack of Commercialisation of Ballast Free Vessel

Despite the potential benefits, ballast-free vessels have not been widely commercialised due to a combination of factors, including industry reluctance, technological limitations, and market dynamics. The key hindrances in the wide spreading adaption of ballast free vessels are:[21]

- Stability and Manoeuvrability Challenges: Achieving the same level of stability, trim, and manoeuvrability in ballast-free ships as in conventional vessels with ballast tanks has proven technically difficult. Maintaining proper bow and propeller submergence, as well as adequate transverse stability, necessitates innovative hull designs and precise weight and buoyancy distribution.

- Regulatory Approval and Compatibility Issues: Ballast-free ship designs often fail to fully comply with existing regulations and standards, which are based on traditional ballast water systems. Obtaining regulatory approval and ensuring compatibility with port infrastructure have been significant challenges.
- Dimensional Constraints and Cargo Capacity: Many vessels have dimensional limitations, such as beam constraints, making it difficult to implement the design changes necessary for a ballast-free solution without compromising cargo capacity. Overcoming these dimensional constraints has proven challenging.
- Challenges in Retrofitting Existing Vessels: Converting existing vessels from traditional ballast water systems to ballast-free designs are particularly challenging, as it often requires extensive modifications to the hull, propulsion, and supporting systems. The costs and logistical complexities involved have deterred widespread retrofitting efforts.
- Market Dynamics: The high initial investment costs and insufficient regulatory pressure, such as from the IMO's Ballast Water Management Convention, have slowed the adoption of ballast-free ships. Benefits like reduced maintenance and increased service life are not immediately realized, making it difficult for ship owners to justify the higher upfront costs.
- Industry Reluctance: The shipping industry's conservatism towards adopting ballast-free vessel designs has hindered their commercialisation. Operators are hesitant to introduce new vessel types due to concerns about seaworthiness and performance.
- Sediment Buildup: Ballast-free designs eliminate the risk of corrosion from sediment buildup in ballast tanks. However, without ballast water management systems, sediment and debris could accumulate in the vessel's internal structures, necessitating additional maintenance.

- Technological Maturity: Many ballast-free concepts, such as continuous flow or monomaran designs, are still in the research and development phase and have not been proven at a commercial scale. These solutions require further validation to ensure their technical feasibility and reliability.

How does the Shear Water Project Shape the Future of Ballast-Free Vessels?

The Shear Water project highlights several critical implications for the future of ballast-free vessel designs. Firstly, it demonstrates the potential for innovative solutions to eliminate the need for ballast water systems, thereby reducing environmental impact and operational costs. The extensive approval process and testing campaigns required for the Shear Water design indicate that significant regulatory and technical hurdles must be addressed for the widespread adoption of ballast-free vessels. However, the project's success in obtaining AiP from multiple classification societies signals growing industry interest and acceptance of ballast-free vessel technologies.

The project's emphasis on improving energy efficiency, reducing emissions, and lowering investment and operating costs aligns with broader industry trends towards more sustainable maritime transport solutions. Additionally, the unique hull shape and integrated permanent ballast system of the Shear Water design provide a valuable template for future ballast-free vessel innovations that can effectively address operational challenges. These developments suggest a promising future for ballast-free vessel technologies in advancing environmentally friendly and cost-efficient maritime operations.

Conclusion

In conclusion, the Ballast-Free Ship (BFS) concept, born out of rigorous research and development at the University of Michigan, emerges as a beacon of innovation to tackle the ecological and operational challenges inherent in traditional ballast water management systems. By integrating pioneering features such as longitudinal structural ballast trunks, which enable the continuous flow of local seawater throughout the vessel, the BFS design effectively mitigates the risks associated with invasive species introduction while offering substantial economic benefits. Extensive testing and analysis have underscored the BFS concept's capacity to maintain stability, achieve fuel savings, and substantially reduce capital costs compared to conventional vessels. Additionally, real-world case studies such as the Shear-Water project by Gaztransport & Technigaz (GTT) exemplify the successful application of BFS principles in designing next-generation LNG feeder and bunker vessels, further validating the feasibility and potential of ballast-free ship technologies.

To catalyse widespread adoption of BFS, regulatory bodies, including the International Maritime Organization (IMO), must spearhead efforts to promote innovation and incentivize the development and implementation of ballast-free vessel technologies. Governments and research funding agencies should bolster investment in research and development, supporting pilot projects and demonstration programs to validate the commercial viability of these technologies.

Furthermore, collaborative efforts between port authorities, infrastructure providers, shipping companies, and fleet operators are essential to ensure seamless integration of ballast-free vessel designs into existing port facilities and operational frameworks. Classification societies and maritime safety organizations play a pivotal role in upholding stringent approval processes, ensuring that these innovative solutions meet or exceed safety and performance standards.

By embracing these multifaceted recommendations, the maritime industry can steer towards a more sustainable and environmentally friendly future. Through collective action, we can mitigate the risks of invasive species introduction, safeguard marine ecosystems, and pave the way for a cleaner, greener maritime sector that benefits both present and future generations.

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ENDNOTES

1 Michael G. Parsons and Miltiadis Kotinis, *Further Development and Optimization of the Ballast-Free Ship Design Concept* (Great Lakes Maritime Research institute and University of Michigan, 2008), 1-25, https://www.glmri.org/downloads/parsons08.pdf

2 Ben Boyd, "Ballast-free ships", *Mewburn Ellis*, 05 December 2023

3 Parsons and Kotinis, *Further Development and Optimization of the Ballast-Free Ship Design Concept* (Great Lakes Maritime Research institute and University of Michigan, 2008), *1-25*, https://www.glmri.org/downloads/parsons08.pdf

4 Sassi J, S Viitasalo, Jorma Rytkonen and Erkki Leppakoski, "Experiments with ultraviolet light, ultrasound and ozone technologies for onboard ballast water treatment," *Valtion Teknillinen Tutkimuskeskus* 2313(2005):1-86 https://www.researchgate.net/publication/273449214_Experiments_with_ultraviolet_light_ultrasound_and_ozone_technologies_for_onboard_ballast_water_treatment

5 Station 17 is near the forward engine room bulkhead

6 Michael G. Parsons and Miltiadis Kotinis, *Refinement of the Ballast-Free Ship Concept* (Great Lakes Maritime Research institute and University of Michigan, 2011), 1-11, https://www.glmri.org/downloads/2010Reports/ParsonsKotinis0910.pdf

7 M. Kotinis, "Development and Investigation of the Ballast-Free Ship Concept," Ph.D. Dissertation, University of Michigan, Department of Naval Architecture and Marine Engineering, (2005)

See Also: Kotinis, M. and Parsons, M. G. 2007 "Hydrodynamic Optimization of the Ballast-Free Ship Concept," Transactions SNAME, 115, 50-67

See Also: M. Kotinis, and Parsons, M. G. 2008/2010 "Hydrodynamics of the Ballast-Free Ship Revisited," SNAME Great Lakes and Great Rivers Section, Fall 2008 Meeting, Ann Arbor, MI; in *Journal of Ship Production and Design*, 26, 4, November 2010, 301-310

8 Parsons and Kotinis, *Refinement of the Ballast-Free Ship Concept* (Great Lakes Maritime Research institute and University of Michigan, 2011), 1-11, https://www.glmri.org/downloads/2010Reports/ParsonsKotinis0910.pdf

9 Wang Hong and Li Huabin, "Comment on Ballast Free Ship", *International Journal of Engineering and Applied Sciences (IJEAS)* : 10.31873/IJEAS.5.12.05, Volume-5, No. 12 (December 2018), 20-22 Comment on Ballast Free Ship (researchgate.net)

10 About Us, Gaztransport & Technigaz, https://gtt.fr/about-us

11 Ballast-water-free, Gaztransport & Technigaz, Shear Water Project - GTT

12 Lorenz Claes, "Shear-Water >> Ballast Water Free LNG Feeder & bunker vessel", (webinar, Bureau Veritas, Hamburg Ship Model Basin (HSVA) and Gaztransport & Technigaz (GTT), YouTube, 2022) https://youtu.be/9KrtY23oOjg?si=Zj1aCA9qkx2DQaPE

13 Azimuth thrusters are an advanced ship propulsion system that provides improved manoeuvrability over conventional systems like propellers and rudders. An azimuth thruster is a configuration of marine propellers placed in pods that can be rotated to any horizontal angle (azimuth), making a rudder redundant. These give ships better manoeuvrability than a fixed propeller and rudder system.

14 *Ibid*

15 Conducting seakeeping performance tests up to NATO Sea-State 7, which corresponds to a significant wave height (Hs) of 7.5 meters, indicates that the vessel was evaluated for its ability to maintain operations and safety even in highly rough sea conditions. The NATO Sea-State scale is a standard classification system used to describe the general condition of the sea surface, ranging from 0 (calm) to 9 (phenomenal). Evaluating the vessel's seakeeping performance up to Sea-State 7 ensures that the design and behaviour of the ship can withstand and operate effectively in severe open-ocean environments.

16 The insulation foam density used in sloshing campaigns was primarily 130 kg/m^3, with some areas using 150 kg/m^3. This density is crucial as it affects the thermodynamic behaviour and boil-off rate (BOR) of the cryogenic liquid cargo within the tanks. The design BOR, based on these insulation foam densities, was 0.165% of the cargo volume per day. This rate is vital for the efficient operation and safety of cryogenic liquid carriers, as it indicates the amount of cargo that evaporates over time. Maintaining the BOR below the design value is essential. Sloshing, the movement of the cryogenic liquid within the tank, can impact thermodynamics and increase the BOR, leading to higher pressure within the tanks. Therefore, proper tank design and effective sloshing management are critical to maintaining the desired BOR for these vessels.

17 Manases T Ruiz, "Shear-Water >> Ballast Water Free LNG Feeder & bunker vessel", (webinar, Bureau Veritas, Hamburg Ship Model Basin (HSVA) and Gaztransport & Technigaz (GTT), YouTube, 2022) https://youtu.be/9KrtY23oOjg?si=Zj1aCA9qkx2DQaPE

See Also: Ballast-water-free, Gaztransport & Technigaz, Shear Water Project - GTT

18 Ballast-water-free, Gaztransport & Technigaz, Shear Water Project - GTT

See Also: GTT Receives AiP from Bureau Veritas for “Shear-Water”, The Maritime Executive, 03 May 2022, GTT Receives AiP from Bureau Veritas for “Shear-Water”

19 The Energy Efficiency Design Index (EEDI) is a technical measure introduced by the International Maritime Organization (IMO) to encourage the use of more energy-efficient equipment and engines in ships. EEDI calculates a vessel’s energy efficiency using a complex formula that considers the ship’s emissions, capacity, and speed. The lower a ship’s EEDI, the more energy-efficient it is, resulting in a reduced negative impact on the environment. EEDI is crucial in the IMO’s efforts to lower the carbon intensity of the global shipping fleet. It serves as a standard for new ship designs, ensuring they meet specific energy efficiency and carbon reduction criteria. By promoting the development and use of more energy-efficient technologies, EEDI helps mitigate the environmental impact of the maritime industry.

20 Lorenz Claes, “Shear-Water >> Ballast Water Free LNG Feeder & bunker vessel”, (webinar, Bureau Veritas, Hamburg Ship Model Basin (HSVA) and Gaztransport & Technigaz (GTT), YouTube, 2022) https://youtu.be/9KrtY23oOjg?si=Zj1aCA9qkx2DQaPE

See Also: Ballast-water-free, Gaztransport & Technigaz, Shear Water Project - GTT

21 Joe Baker, “Could ballast-free shipping be the best route to IMO compliance?”, *Ship Technology*, 07 August 2018. https://www.ship-technology.com/features/ballast-free-imo/?cf-view

See Also: P Ramani and V Sasirekha, “Management of Ballast Water - Ballast Free Shipping - The Way Forward”, *AMET International Journal of Management*, ISSN 2231-6779 (Jan - June 2014): 1-12 MANAGEMENT OF BALLAST WATER - BALLAST FREE SHIPPING - THE WAY FORWARD

Emerging Trends in Ship Recycling Market: An Analysis of Determining Factors

Dr Emil Mathew

Fluctuations in the shipping market exert an impact on related markets of shipping freight, ship building, ship resale, and ship demolition. Developments in international trade directly influence shipping market services, leading to up-or-down shipping market cycles.[1] Generally, an increase in the demand for shipping services raises the freight rates, bringing economic prosperity to ship owners, who are less inclined to demolish ships at these times. During an economic downturn, freight rates drop, impacting the revenue of ship owners, making it difficult to even recover the operating cost of the vessels. At these times, they prefer to sell their obsolete and inefficient vessels to ship recycling yards to make up for lost revenue. Besides the technical and physical obsolescence of ships, the lifespan of vessels as determined by international and national regulations on shipping also determines the journey of end-of-life of vessels to demolition yards.

A majority of the end-of-life vessels end up in the ship recycling yards of Alang in India, Chittagong in Bangladesh, and Gadani in Pakistan for dismantling and demolition. Ship recycling in these locations ensures jobs and supply of scrap steel besides contributing to the respective nation's GDP. The recycling yards directly employ many unskilled labourers migrating from interior parts of the country on a temporary or contractual basis and indirect job opportunities are also generated in allied activities.[2] However, the ship recycling industry has attracted severe criticism for being insensitive to environmental protection and being indifferent to workers' safety and security during recycling operations. Studies have highlighted more risk and danger for workers in ship recycling yards than those who work in mines, which is considered to be the riskiest job.[3] Also, poor living conditions of the workers impact their health and quality of life.[4] This dire situation has impelled national and international organisations to issue guidelines and policies to regulate ship recycling operations so that they are human-centric and environmentally benign.

As the ship recycling yard owners focus on bringing down the cost of recycling and maximising revenue, they show the least concern for workers' safety or environmental protection. Growing environmental awareness and heightened media attention on the deplorable working conditions have forced recycling nations to enforce regulatory mechanisms to monitor and control yard operations to prevent undue exploitation of workers and the environment. For yard owners, revenue realised from retrieved or recycled materials including scrap steel extracted from demolished vessels, cost of recycling operations, and compliance with national and international regulations of recycling are determining factors of the volume of vessels recycled. Reuse and recycling ensure the longevity of the materials in use.[5] In the ship recycling nations, 90% of the materials are reused and recycled, thus mitigating the pressure to extract natural resources, especially iron ore. The ship recycling industry supplies 7%, 60%, and 10% of recovered scrap steel to the domestic steel industry in India, Bangladesh, and Pakistan, respectively, and its contribution to the infrastructural development of Bangladesh is commendable.[6]

Many stakeholders – ship owners, yard owners, national and international regulators, cash buyers, i.e., middlemen between ship owners and yard owners, besides a large number of yard workers without any decisive powers – influence market transactions in the ship recycling market. As the fortunes of the ship recycling market are determined by the changes in the international shipping market,[7] it is important to examine how fluctuations in the shipping market affect the ship recycling markets in India. Along with demand and supply determinants in the international shipping markets, national and international regulations also can impact the market for ship recycling. One such factor is India's Recycling of Ships Act 2019. This Act stipulates standard operating procedures to be followed for all the ship recycling yards in India to incorporate environment-centric and worker-friendly mechanisms and measures. The additional financial investment required to upgrade the facilities of the yards results in higher costs and lowering of profits, ultimately weakening the competitiveness of the Indian recycling yards. On the other hand, the recycling yards in the neighbouring nations where these stipulations are not in force, offer their services at competitive rates to prospective customers.

The first section of this paper examines the major demand and supply determinants of the ship recycling market. This is followed by an analysis of the latest ship recycling market trends. The paper examines the prevalence of different standards of regulation on ship recycling and their impact on the competitiveness of ship recycling yards in India. It also explores the issue of change of flags of end-of-life vessels, a practice widely considered by experts as one of the major loopholes of the Hong Kong Convention. The paper concludes with the suggestion that uniform measures may be administered internationally for the long-term sustainability of the marine environment and also for the safety of the workers.

Determinants of Supply in the Ship Recycling Market

Ship owners are highly vigilant about the fluctuations in freight rates as they have a direct impact on their profitability. The age of the vessels is a significant concern as it affects the performance and obsolescence of ships. Additionally, they closely monitor and update themselves to comply with international maritime regulations that affect their operations. A favourable market for international trade reduces the supply of ships to the recycling market, and the opposite is true in the case of an unfavourable market.

Freight Rates

Knapp et al. (2007)[8] observed a negative relationship between earnings from ships and the rate of scrapping of ships. When freight rates are soaring, all rational ship owners look to utilise the existing shipping services intensely, either by prolonging the life of the existing ships or by adding new or second-hand ships to their fleet. In a booming economy, ship owners may be least interested in selling their ships to cash buyers, the intermediaries of the recycling market for demolition. In other words, ship owners send their obsolete ships to recycling yards if the costs of their operations exceed the revenue earned.

Freight indices vary for different shipping markets and Baltic freight indices for containers, dry bulks, and dirty tankers represent the major trends in the shipping market. Table 1 shows the freight rates for the last six years, which signify a global demand for shipping services.

Table 1: Freight Market Indices (USD)

Years	Container index	Dry bulk index	Dirty tanker index
Jan 2017	1524	1356*	835
Jan 2018	1203	1152	664
Jan 2019	1414	668	848
Jan 2020	1461	487	882
Jan 2021	3452	1452	517
Jan 2022	9293	1418	689

**Indicates figure in Sept. 2017.*

Source: Compiled from Baltic Dry Index, 2022, investing.com;[9] Baltic Dirty Tanker, 2022 investing.com;[10] Freightos Data, 2022;[11] Statista Research Department (b), 2022.[12]

Container and dry bulk markets improved since January 2021 after experiencing a severe fall during the pandemic. However, the market for dirty tankers that transport petroleum products that were contracted in 2021 is slowly picking up. The slump in the global economy at the beginning of 2020 lowered the demand for shipping services, leading to drop-in freight rates. The lockdowns and travel restrictions curtailed demand for oil tanker services, lowering the index for dirty tankers in 2021. Restricted logistics operations, caused by the pandemic, led to a shortage in equipment and containers, unreliable services, congested ports, longer delays and dwell times, but indices of container and dry bulk markets moved up in 2021 and 2022. Logistics operations suffered further delays due to the closure of the Suez Canal following the grounding of Ever Given, one of the largest container ships owned by Taiwanese company Shoei Kishen Kasha, widening the gap between shipping demand and the realised ability of the market to cater to the demand[13] and causing an increase in freight rates. The new ship building market also could not furnish the demand positively as shortages in labour supply plunged the delivery of new vessels by 12%.[14] Thus, an inelastic supply from new building market to meet the increased demand for shipping services led to an increase in freight rates, consequently causing escalation of rates in the resale vessels market too. Thus, after the pandemic, recycling market saw a scanty supply of end-of-life vessels.

Age of the Vessels

The physical and technical efficiency of ships to function competitively is an important factor determining their physical obsolescence and there is a positive correlation between age of the vessel and scrapping. The average life of a vessel is over 20 years but varies for different categories of ships; general cargoes have a higher lifetime of 26 years.[15] In 2021, 42% of the ships were aged more than 20 years globally, with the average life of the vessels being 21.6 years (21.2 years in 2020).[16] A sizeable number of older ships in the global shipping market likely pushes up demand for recycling operations. Ship owners are less incentivised to invest on vessels nearing end-of-life to enhance safety standards and on other maintenance and repair works.[17] Older vessels entail a higher operational and maintenance cost, so owners prefer to recycle ships if the earnings do not cover the cost of operations. Moreover, older ships display a poor performance and cause enhanced greenhouse gas (GHG) emissions.[18]

Shipping Regulations

Both operating and to-be-demolished ships are required to comply with the International Maritime Organization's (IMO) regulations on the sulphur content of ship fuel oil and those on decarbonisation, and Conventions on Ballast Water Management.[19] As part of the IMO's initial strategy to reduce GHG emissions from ships, IMO members agreed in 2018 to reduce annual GHG emissions from shipping by at least 50% by 2050 compared to the 2008 levels. Decarbonisation can be achieved only if zero-emission ships enter the global fleet by 2030 by either through technology change or fleet renewal.[20] Considering the heavy investment required to replace the old technology for lowering GHG emissions, ship owners generally prefer to demolish vessels that do not meet regulatory requirements. Thus, the ships are sent for recycling, if the capital expenditure required to convert the existing into environment-friendly ships exceeds the expected future cash proceeds.

Determinants of Demand in the Ship Recycling Market

More than 90% of the global shipping recycling operations are handled by recycling yards in India, Bangladesh and Pakistan. Recyclers realise revenue from scrap steel and other retrieved materials. They incur expenses in the form of labour charges, tax paid to the government, and the cost of recycling operations. Recycling yards in the Indian subcontinent resort to several cost-cutting measures to enlarge their profits compared to yards elsewhere in the world. They save on operations cost because of cheap labour, lack of environmental safety standards, absence of medical insurance for temporary and contract workforce and lack of proper waste disposal and management practices. Ship owners sell off their vessels to such yards with potentials to offer competitive rates.[21]

Prices of Scrap Steel and Other Recovered Materials from End-of-Life Ships

The scrap steel recovered from the recycled ships is in high demand from the steel rerolling industry operating near the yard. Moreover, domestic industries procure second-hand steel from recycling yards, reducing the burden on steel-making industry.[22] For example, in Bangladesh, scrap steel supplied by ship recycling yards constitute 60% of the demand for raw material from approximately 350 local steel industries.[23] In Karachi, Pakistan, around 70% of the ship scrap steel sent to rerolling mills generated about 95% of the revenue from recycling.[24] Rahman and Kim's (2020)[25] study found that supply of scrap steel positively contributes to industrial development. Thriving second-hand markets also exist for retrieved machineries, equipment and other materials near the recycling yards of these nations.

Cost of Ship Recycling Operations

Ship recycling yard owners incur expenditure such as labour cost, cost of clean-up of environment, import duties, costs of training and protective equipment for workers besides the procedural cost of ship recycling. These costs vary between developed and developing nations, and also on the yard owners' willingness to adopt responsible recycling. Ship recyclers incur both the fixed costs (yard costs, ship purchasing costs, etc.) and variable costs (taxes and duties, waste disposal costs, labour costs, etc.).[26] Moreover, ship recycling operations encompass monetary costs and non-monetary costs. The externalities imposed on the workers and the marine environment are the non-monetary costs, which are not internalised into the system. After completing the final sale of ships, ship owners escape responsibility for any such costs, though the 'polluter pays principle' needs to be enforced on ship owners.[27]

There are two types of risks in the recycling process: risks due to the toxicity of hazardous materials and occupational risks.[28] Ship recycling is labour-intensive, but yard owners in Alang, Chittagong, and Gadani have access to cheap labour, saving further on operations costs. Most of the workers are unskilled migrant labourers employed on a contractual basis, not protected by labour laws. They are not provided protective equipment and formal training and therefore unaware of the potential threats of working in a hazardous environment. Those sustaining severe injuries and even meeting with fatal accidents do not receive compensation. Several studies highlight the occupational hazards of ship recycling,[29] but they focus only on short-term implications, leaving aside the long-term effects of recycling operations on workers' health.[30] Workers live in unhealthy surroundings without basic amenities, experiencing a poor quality of life. Moreover, the method of beaching in recycling operations leave the coastal areas with oil and bilge that permeate to the ground, posing a serious hazard to the marine environment and biodiversity. These costs are never internalised, and thus does not affect the final cost of recycling operations.[31] The Hong Kong Convention on Safe and Sound Recycling of Ships 2009 (HK Convention) provides directions regarding the treatment, storage and disposal of hazardous materials. In the absence of stringent regulations to penalise such unhealthy practices, the yard owners engage in exploitative activities, resulting in the generation of negative externalities.

The external cost of recycling operations is also highly influenced by the recycling methods such as beaching, slipway, alongside/buoy and dry dock. Each method has its own advantages and disadvantages. Beaching is considered to be more profitable among them and yards in the Indian subcontinent enjoy the geographical advantage of dismantling ships during the intertidal zone of the beach. However, it imposes costs on the environment and workers, but these externalities are the implicit costs of recycling that are often neglected.[32]

Yard owners are not motivated to invest on capital and operations to comply with the Hong Kong Convention.[33] If the recycling nations have adopted international recycling regulations, yards would be legally bound to abide by domestic laws. In India, the Recycling of Ships Act 2019 mandates statutory standards in ship recycling operations and all the recycling yards operating in India are legally bound to get approval from the National Authority of Ship Recycling to perform their operations. The Act directs yard owners to invest in protective equipment and training for workers, basic hygiene and medical facilities, and proper handling, treatment and disposal of wastes to improve performance. The profitability of the yard is also affected by tax and import duties imposed on recycling operations. In India, Integrated Goods and Services Tax is high at 18% of the light displacement tonnage recycled compared to 12% and 17% in Bangladesh and Pakistan, respectively.[34] This naturally raises the cost of recycling operations in the Indian yards, weakening their competitiveness.

Regulations of Recycling Operations

IMO's guidelines on responsible recycling and International Labour Organisation's (ILO) labour directives have far-reaching implications on the domestic policies of IMO member states. Similarly, environmentally responsible policies of a nation can influence its domestic policies of ship recycling. Realising the environmental and health hazards of ship recycling, many developed nations moved ship recycling operations to nations with lax laws. Ship recycling operations therefore shifted to the Indian subcontinent by the mid-1980s.[35] During the mid-1990s, China garnered almost 50% of the recycling market for end-of-life ships but imposed stricter national environmental regulations later, ending its import of foreign vessels.[36] The regulations came into force in China on 1 January 2019, following which a major share of ship recycling operations shifted to other nations. As Chinese yards took a hit, the Chinese government subsidised the recycling of Chinese-flagged ships to encourage them to continue recycling in their yards.[37]

The Hong Kong Convention 2009 marks a significant milestone in regulating recycling operations. It will enter into force 24 months after it is ratified by 15 nations with 40% of the global merchant fleet earning a recycling capacity of at least 3% of their fleets. The RSA 2019 of India emphasises responsible recycling and imposes punishments with penalties on yard owners deviating from the stipulated norms. Since India is a party to the Hong Kong Convention, it was expected that the UN member states would be interested in sending their ships to Indian yards. However, the additional investment incurred to improve the ship recycling standards is likely to shrink the competitiveness of Indian yards.

Though the Hong Kong Convention is hailed as a breakthrough, it is not devoid of defects. The loopholes in international regulations like the Hong Kong Convention and European Union Ship Recycling Regulation (EUSRR), the regulation applicable to the EU ships, to penalise and prevent the change of flags to flags of convenience provide opportunities to the ship owners to make financial gain during the last voyage of end-of-life ships. According to Knapp et al. (2007),[38] flag registrations of vessels indicate the relative importance the ship owner has placed on the safety, and security along with its journey towards scrapping. The discrepancies in the international regulations, coupled with lax domestic laws, create a favourable ground to ship owners to sell their old ships to South Asian yards. NGO Shipbreaking Platform reports that more than 75% of the ships dismantled in South Asian yards in the second half of 2021 changed their flags to grey and black registries such as Comoros, St. Kitts, Nevis, Gabon and Palau just a few weeks before arriving at the yards.[39] Ships using these registries, which are popular among the cash buyers who purchase vessels to resell them to the recycling yards but are not preferred during the operational life, earn certain discounts during their last voyage. Sheikh (2021)[40] and Alcaidea and others (2016)[41] observed that by changing flags in order to recycle in non-party states, ship owners enjoy higher revenues than recycling in Hong Kong Convention complying yards. Out of 20% of the EU-flagged ships in their operational life, only 9% remain with the EU flag when they reach recycling yards.[42] So, two parallel ship recycling markets operate now: party states acceding the Hong Kong Convention and non-party states that do not comply with the Convention.[43]

Ship Recycling Market: Recent Trends

Bangladesh, India, Pakistan, China and Turkey are the final destinations for over 95% of end-of-life vessels. China banned importing foreign vessels for recycling but encourages recycling domestic ships with government subsidies. Recycling in China would reach a commendable volume if Chinese ship owners prefer to recycle in domestic yards, as China is the third largest ship owning country. With the strict enforcement of the EUSRR since 2019, European nations prefer EU complying yards and the relative share of Turkey in the recycling market is likely to increase, as it has many EU complying yards. Table 2 presents the annual gross tonnage of ships recycled and the annual share of major recycling nations.

Table 2: Annual Gross Tonnage of Ships Recycled ('000 GT)

Ship-recycling nations	2014	2015	2016	2017	2018	2019	2020	2021
Bangladesh	4421 (19.60)	8065 (34.34)	9530 (32.41)	6693 (28.93)	8639 (45.60)	6690 (55.60)	6996 (40.66)	7992 (52.13)
India	6928 (30.71)	5156 (21.95)	9467 (32.20)	6776 (29.29)	4649 (24.54)	3278 (27.25)	5026 (29.21)	2700 (17.61)
Pakistan	4140 (18.35)	4521 (19.25)	5480 (18.64)	4137 (17.88)	3986 (21.04)	328 (2.72)	3100 (18.01)	3028 (19.75)
China	5341 (23.67)	4492 (19.13)	3518 (11.96)	3777 (16.32)	466 (2.46)	343 (2.85)	195 (1.14)	140 (0.91)
Turkey	933 (4.14)	835 (3.55)	980 (3.33)	1325 (5.73)	782 (4.13)	1104 (9.18)	1601 (9.30)	1036 (6.76)
Others	797 (3.53)	418 (1.78)	428 (1.46)	430 (1.86)	423 (2.23)	289 (2.40)	289 (1.68)	433 (2.83)
World	22561 (100)	23487 (100)	29403 (100)	23138 (100)	18945 (100)	12031 (100)	17208 (100)	15329 (100)

Note: Figures in brackets indicate the annual share of each nation in the respective years.

Source: UNCTAD 2021. www.unctadstas.unctad.org

Currently, more than 90% of the ships are recycled in Bangladesh, India and Pakistan. The share of these nations in ship recycling and their ranking underwent significant transformations over the years. In 2014, by gross tonnage, India was ranked first in recycling operations followed by China, Bangladesh, Pakistan and Turkey. Since 2017, ship recycling volumes dropped in all recycling nations, but this reduction was noticeable predominantly after 2019. In 2020, the volumes spiked slightly due to the economic downturn at the beginning of the pandemic. The share of Bangladesh in ship recycling and recycling volume has been rising consistently over the years, and it is the top recycling nation since 2018. India, which was ranked first at the beginning of the decade, experienced a reduction in the volume and share of ship recycling, and its rank has dropped. Pakistan, another competing nation in South Asia, slightly improved its position and share after the pandemic, from third to second position. The share of China declined significantly over the years, whereas the share of Turkey increased moderately during the same period, and it is expected to increase considerably in the immediate future as many environmentally sensitive ship owners of the EU are likely to navigate their end-of-life vessels in Turkish yards due to the stringent EUSRR. Market analysis clearly shows declining volume, share and position of India in ship recycling over the years. Recently, India acceded to the Hong Kong Convention, following which, many Hong Kong Convention complying recycling yards are available in the country. It is interesting to examine the role of the RSA 2019 and also the pandemic on the ship recycling industry in India to gauge the reasons, especially the role of external factors, behind India's declining position.

Hong Kong Convention 2009 and Recycling of Ships Act 2019

The Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and Their Disposal 1989 is the first international Convention designed to regulate the transboundary movement of hazardous wastes including end-of-life vessels. Under this, the state of export is bound to seek the consent of the state of import before the disposal and often ship owners contravened its clauses.[44] Ship recycling as an industry received international attention mainly because of the nature of occupational hazards and also due to its adverse impacts on the marine environment and biodiversity.[45] The member nations of the ILO and the IMO deliberated on the necessity of developing sustainable and sound ship recycling practices. In 2005, the IMO passed a resolution requesting the Marine Environmental Protection Committee (MEPC) to propose environmentally sound methods of recycling. Further deliberations held in Hong Kong in 2009 led to the adoption of the Hong Kong Convention for Safe and Environmentally Sound Recycling of Ships. The Hong Kong Convention 2009 covers different stages of the life of a ship, its design, manufacturing, operations, recycling preparation, and demolition. According to this guideline, the ship owners need to produce the certificate of Inventory of Hazardous Materials and Certificate of Compliance and recycling yards to declare the Ship

Recycling Facility Management Plan and Ship-specific Recycling Plan.[46] It will enter into force 24 months after it has been ratified by 15 nations that represent 40% of the merchant shipping by gross tonnage and also it satisfies a maximum annual volume of recycling of not less than 3% of the combined tonnage of the recycling nations.[47] Though it has been considered as a major breakthrough in the ship recycling operations, the guideline is not devoid of defects, including no alternatives suggested for beaching, no coverage of ships below 500 GT, unequal sharing of responsibility between ship owners and ship recycling nations, no provisions to stop the change of flags of end-of-life vessels and ignored 'polluter pays principle.'[48]

India, a major ship recycling nation, entered into ship recycling operations as early as 1980. The arrival of the French passenger liner Blue Lady in 2007 to Alang was opposed by environmental activists and later the matter was brought to the consideration of the Supreme Court.[49] As directed by the Court, a guideline called Ship Breaking Code 2013 to regulate the ship recycling industry was framed after drawing from the provisions of the Hong Kong Convention. India ratified the Hong Kong Convention in 2019 by enacting the Recycling of Ships Act. It is mandatory for recycling yards operating in India to strictly adhere to standard operating procedures and practices while dismantling ships. Ahmad (2022)[50] stated that these regulations of the Act need to be complemented by India-specific rules and norms. It was expected that adherence to the Act would lead to an influx of end-of-life vessels from environmentally conscious nations.[51] Rather it brought down the number of ships arriving at Indian yards (Table 2) due to the cost-efficient recycling opportunities offered by neighbouring nations. The incorporation of standards necessitated the yard owners to invest in worker-friendly and environment-friendly measures and mechanisms which brought down the competitiveness of the Indian recycling yards.

Discussion

The demand and supply determinants of the ship recycling market are uniformly applicable to all nations. Since Hong Kong Convention has not yet been in force, those nations which ratified the Convention follow stringent regulations either as ship recycling nations or as ship owning nations. The ratification of the Hong Kong

Convention by a few nations led to the coexistence of yards that comply with the Convention and those that do not comply with the Convention in ship recycling markets. For those nations that adopt the Convention, ship recycling regulations can vary subject to the stringency of such regulations in their respective nations. In the case of the EU nations, EUSRR norms are more stringent as they do not support beaching, maintain high standards for the downstream treatment of wastes, and emphasis greatly on labour rights. On the other hand, the non-compliant yards tend to maximise their profit without incurring any additional investment costs. Thus, acceding to the Hong Kong Convention makes the Indian yards less attractive and competitive and this has brought down the gross tonnage of ships recycled in India.

Another issue associated with the ship recycling operations that has not been addressed by the Hong Kong Convention is the change of flags of end-of-life vessels. According to Knapp et al. (2007),[52] flag registrations of vessels indicate the relative importance the ship owner has placed on the safety, and security along with its journey towards scrapping. The discrepancies in international regulations, coupled with lax domestic laws, create a favourable ground for ship owners to sell their old ships to South Asian yards. NGO Shipbreaking Platform reports that almost half of the ships dismantled in South Asian yards in 2023 changed their flags to grey and black registries such as Comoros, St. Kitts, Nevis, Gabon, and Palau just a few weeks before arriving at the yards.[53] Ships using these registries, which are popular among the cash buyers who purchase vessels to resell them to the recycling yards but are not preferred during the operational life, earn certain discounts during their last voyage. Sheik (2021)[54] and Alcaidea and others (2016)[55] observed that by changing flags to recycle in non-party states, ship owners enjoy higher revenues than recycling in the Hong Kong Convention complying yards. Out of 20% of EU-flagged ships in their operational life, only 9% remain with the EU flag when they reach recycling yards.[56] The Convention does not provide any provisions to stop the change of flags of end-of-life vessels. As long as those end-of-life ships that changed their flags are welcomed by non-party states, there will be double standards and hence ship owners prefer cost-effective markets.

The ratification of the Hong Kong Convention by India through the RSA 2019 led to strict compliance with the Convention's regulations on workers' safety and the adoption of environment-friendly measures in India.[57] Since the Hong Kong Convention has not been made universally obligatory, global variations in the enforcement of recycling regulations and environmental concerns have produced parallel markets in the ship recycling industry. As long as the system provides flexibility to change flags to states of convenience, even the party states prefer to recycle in non-party states. For yards to comply with the Hong Kong Convention, yard owners have to invest in a set of procedures for cleaning up the environment, impart training to workers, ensure proper protective measures, support workers with medical facilities, enforce proper treatment, handle and dispose of hazardous wastes, all of which raise the cost of recycling, cutting into the profitability of the yard operations. On the other hand, cost-effective non-party recycling yards in neighbouring recycling nations attract more ships which indirectly brings down the competitiveness of Indian yards.[58] In the absence of provisions to check change of flags under the Hong Kong Convention and EUSRR, even the EU and party states of the Hong Kong Convention can sell their end-of-life vessels to non-party recycling yards, further weakening India's competitiveness in the market.

Another external factor that hit the ship recycling market adversely at the beginning of this decade is the closure of economic activities during the COVID-19 pandemic. Ships sold for recycling to the yards of the Indian subcontinent were not able to arrive because of restrictions on crew movements due to lockdown-induced flight cancellations.[59] The volume of recycling drastically dropped. As the migrant labour force hailing from interior parts of the countries left for their homes immediately after the lockdown, yards in Alang, Chittagong and Gadani suffered manpower shortages.[60] Further, the recycling operations at Alang were hit by a shortage in oxygen supply as the government imposed restrictions on the supply of oxygen to industrial activities during the pandemic.[61] Thus the number of ships sailing for recycling to the Indian subcontinent slumped which later on improved.

Conclusion

Ship recycling is a process of extracting equipment, materials, and machineries of economic value from end-of-life vessels for resale or reuse and removing hazardous materials before dismantling them for scrap steel.[62] Freight rate variations bring out the trends in the ship recycling market. The supply-side determinants of ship recycling are freight rates, age of the vessels, and ship recycling regulations whereas the demand-side factors are earnings from recycling, cost of recycling, and ship recycling regulations. In a ship recycling market, demand depends mainly on the availability of ships for scrapping, although it is influenced by a set of demand determinants. In the light of the discussions on the factors that influence the ship recycling market operations, it has been learnt that along with the demand and supply determinants, the external factors also have decisive roles in determining the volume of ship recycling.

Since 2020, the shipping market witnessed an increase in freight rates which led to a decline in ship recycling operations in all the recycling nations. The passing of the RSA 2019 in India necessitated yard owners to invest in procedures of responsible recycling and worker safety, which made the recycling operations expensive for Indian yards and therefore adversely affected the yard's profitability. The cost-effective competing yards in the neighbouring nations have been able to attract lucrative ship owners from non-party states as well as from party states who are keen to change their flags to flags of convenience. Summing up, the passing of RSA 2019 and the pandemic that followed had an adverse effect on ship recycling operations in India whereas in Bangladesh and Pakistan, recycling volume has gone up.

The recent fluctuations in the ship recycling markets have shown how a host of factors including national and international regulations, exigencies like pandemics and other factors play important roles in determining the demand-supply dynamics of these markets. There is no uniform commitment to adhere to international conventions on safe ship recycling practices among the ship-recycling nations and this has a direct impact on the recycling markets. Offering cheaper recycling facilities, though may be beneficial to their national economy in the short run, is neither sustainable nor beneficial to the environment and the workers of these nations in the long run. The competition among the recycling nations to attract end-of-the-life ships must not be at the cost of long-term commitment to the environment and human safety. There is an urgent need to bring in uniform compliance from all recycling nations on international regulations so that ship recycling will emerge as a stable, sustainable and economically productive activity.

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ENDNOTES

1 Martin, Stopford. "MARITIME ECONOMICS," 2009. https://logistics.nankai.edu.cn/_upload/article/50/93/1cf2097840e8af90af4b19979773/9ce547df-a3e1-493c-a4a3-0ebbfe0669b9.pdf

See Also: Karlis, Thanasis, and Dionysios Polemis "Ship Demolition Activity" *Pomorstvo* 30, no 2 (December 23, 2016): 128–32. https://doi.org/10.31217/p.30.2.5 ; Mikelis, Nikos The Recycling of Ships 1st ed, 2018 *and* Gourdon, Karin "OECD Science, Technology and Industry Policy Papers" *OECD Science, Technology and Industry Policy Papers*, no 68 (April 12, 2019). https://doi.org/10.1787/23074957

2 Geetanjoy, Sahu. "Workers of alang-sosiya: a Survey of working conditions in a ship-breaking yard, 1983-2013" *Economic and Political Weekly* (2014): 52-59

See Also: Khandakar Akhter, Hossain" Overview of ship recycling industry of Bangladesh" *Journal of Environmental & Analytical Toxicology* 5, no 5 (2015): 1-7

3 Demaria, Federico. "Shipbreaking at Alang–Sosiya (India): an ecological distribution conflict" *Ecological economics* 70, no 2 (2010): 250-260

See Also: Sahu, Geetanjoy "Workers of alang-sosiya: a Survey of working conditions in a ship-breaking yard, 1983-2013" *Economic and Political Weekly* (2014): 52-59

4 Sahu, Geetanjoy "Workers of alang-sosiya: a Survey of working conditions in a ship-breaking yard, 1983-2013" *Economic and Political Weekly* (2014): 52-5

See Also: Terao, Tadayoshi "From shipbreaking to ship recycling: the relocation of recycling sites and the expanding international approach" in *Economic Integration and Recycling in Asia: An Interim Report* (2011): 113-127;

Liu, Yi-Kuen, Guang-Yang Yang, Trong-Neng Wu, Ruey S. Lin, and Fung-Chang Sung. "Mortality among Former Shipbreaking Workers—A 13-Year Retrospective Follow-up Study in Taiwan" Journal of Occupational Health 45, no 1 (2003): 36-42;

Pastorelli, Silvia "EU Ship Recycling Regulation: What's in it for South Asia" Brussels: European Institute for Asian Studies (2014)

5 Sornn-Friese, Henrik, Eva Roth, Petar Sofev, Brooks Kaiser, Knud Sinding, Hanna Vagsheyg, Andrea Eikås et al "Creating circular economy clusters for sustainable ship recycling in Denmark" (2021)

6 Sheikh, Wahidul "Retaining competitive advantage in ship recycling under the new regulatory framework: a case study of Bangladesh" (2021)

7 Stopford, Martin "MARITIME ECONOMICS," 2009

8 Knapp, Sabine, Shashi Kumar, and Anna Bobo-Remijn The ship recycling conundrum: an econometric analysis of market dynamics and industry trends No EI 2007-52. 2007

9 Baltic Dry Index (BADI). "Baltic Dry Index" *Investingcom India*, 2022 https://in.investing.com/indices/baltic-dry

10 Baltic Dirty Tanker (BAID) "Baltic Dirty Tanker Historical Rates" *Investing.com* India, 2022. https://in.investing.com/indices/baltic-dirty-tanker-historical-data?end_date=1660051438&st_date=1483986600&interval_sec=monthly

11 Freightos. "FBX HOMEPAGE." *Freightos*, 2022. https://fbx.freightos.com.

12 Statista Research Department (b). "Baltic Dry Index Monthly 2018-2023." *Statista*, October 2023. https://www.statista.com/statistics/1035941/baltic-dry-index

13 UNCTAD "Review of Maritime Transport 2021" United Nations Conference on Trade and Development, 2021 https://unctad.org/system/files/official-document/rmt2021_en_0.pdf

14 UNCTAD. "Review of Maritime Transport 2021" United Nations Conference on Trade and Development, 2021 https://unctad.org/system/files/official-document/rmt2021_en_0.pdf

15 Statista Research Department (a). "World Merchant Fleet - Age by Vessel Type 2019-2020." *Statista*, November 2022. https://www.statista.com/statistics/1102442/age-of-world-merchant-fleet-by-vessel-type/

16 UNCTAD "Review of Maritime Transport 2021" United Nations Conference on Trade and Development, 2021 https://unctad.org/system/files/official-document/rmt2021_en_0.pdf

17 Knapp, Sabine, Shashi Kumar, and Anna Bobo-Remijn The ship recycling conundrum: an econometric analysis of market dynamics and industry trends No. EI 2007-52 2007

18 Olmer, Naya, Bryan Comer, Biswajoy Roy, Xiaoli Mao, and Dan Rutherford "Greenhouse gas emissions from global shipping, 2013–2015 Detailed Methodology" *International Council on Clean Transportation*: Washington, DC, USA (2017): 1-38

19 UNCTAD. "Review of Maritime Transport 2021" United Nations Conference on Trade and Development, 2021. https://unctad.org/system/files/official-document/rmt2021_en_0.pdf

20 Hoffmann, J "Decarbonizing maritime transport: Estimating fleet renewal trends based on ship scrapping patterns" In UNCTAD (United Nations Conference on Trade and Development): Geneva, Switzerland. 2020

21 Shah, Sayed Asghar, Hadi Hussain, and Mujahid Hussain "Skill gap analysis in the ship breaking industry of Pakistan" *American Journal of Industrial and Business Management* 7, no 11 (2017): 1244-1254

See Also: Frey, R. Scott "Breaking Ships in the World-System: An Analysis of Two Ship Breaking Capitals, Alang-Sosiya, India and Chittagong, Bangladesh" Journal of World-Systems Research, February 26, 2015, 25–49 https://doi.org/10.5195/jwsr.2015.529; Sahu, Geetanjoy "Workers of alang-sosiya: a Survey of working conditions in a ship-breaking yard, 1983-2013." *Economic and Political Weekly* (2014): 52-59; Demaria, Federico "Shipbreaking at Alang–Sosiya (India): an ecological distribution conflict" *Ecological Economics* 70, no 2 (2010): 250-260

22 Karlis, Thanasis, and Dionysios Polemis "Ship Demolition Activity" Pomorstvo 30, no 2 (December 23, 2016): 128–32. https://doi.org/10.31217/p.30.2.5

See Also: Nikos The Recycling of Ships 1st ed., 2018

23 Das, Jewel, and Muhammed Ali Shahin "Ship breaking and its future in Bangladesh" Journal of *Ocean and Coastal Economics* 6, no 2 (2019): 9

24 Ahmed, Rukhsar, and Kamran Siddiqui "Ship breaking industry in Pakistan–problems and prospects" *International Journal of Managment, IT and Engineering* 3, no 9 (2013): 140-155

25 Rahman, SM Mizanur, and Junbeum Kim "Circular economy, proximity, and shipbreaking: A material flow and environmental impact analysis" *Journal of Cleaner Production* 259 (2020): 120681

26 Sheikh, Wahidul "Retaining competitive advantage in ship recycling under the new regulatory framework: a case study of Bangladesh" (2021)

27 Rahman, SM Mizanur "A critical review of shipbreaking literature reveals shortcomings in dimensions considered for sustainability" (2020)

See Also: Jain, Kanu Priya, J F J Pruyn, and J J Hopman "Critical analysis of the Hong Kong international convention on ship recycling" *International Journal of Environmental and Ecological Engineering* 7, no 10 (2013): 684-692

See Also: Poddar, Paridhi, and Sarthak Sood "Revisiting the Shipbreaking Industry in India: Axing Out Environmental Damage, Labour Rights' Violation and Economic Myopia" *NUJS* Rev 8 (2015): 245

28 Tanha, Moutushi, Grant Michelson, Mesbahuddin Chowdhury, and Pavel Castka. "Shipbreaking in Bangladesh: Organizational responses, ethics, and varieties of employee safety" Journal of *Safety Research* 80 (2022): 14-26

29 Sahu, Geetanjoy. "Workers of alang-sosiya: a Survey of working conditions in a ship-breaking yard, 1983-2013" *Economic and Political Weekly* (2014): 52-59

See Also: Hossain, M. Shahadat, Sayedur R. Chowdhury, SM Abdul Jabbar, S. M. Saifullah, and M Ataur Rahman. "Occupational health hazards of ship scrapping workers at Chittagong coastal zone, Bangladesh." *Chiang Mai J Sci* 35, no 2 (2008): 370-381

30 Rahman, SM Mizanur "A critical review of shipbreaking literature reveals shortcomings in dimensions considered for sustainability" (2020)

31 Frey, R Scot "Breaking Ships in the World-System: An Analysis of Two Ship Breaking Capitals, Alang-Sosiya, India and Chittagong, Bangladesh" *Journal of World-Systems Research*, 26 February, 2015, 25–49 https://doi.org/10.5195/jwsr.2015.529

See Also: Mikelis, Nikos . The Recycling of Ships 1st ed., 2018

32 Poddar, Paridhi, and Sarthak Sood "Revisiting the Shipbreaking Industry in India: Axing Out Environmental Damage, Labour Rights' Violation and Economic Myopia" *NUJS L.* Rev. 8 (2015): 245

33 Sheikh, Wahidul "Retaining competitive advantage in ship recycling under the new regulatory framework: a case study of Bangladesh" (2021)

See Also: Jain, Kanu Priya, Jeroen Pruyn, and Hans Hopman "Strategic guidance based on the concept of cleaner production to improve the ship recycling industry" *Environment Systems and Decisions* 38, no 2 (2018): 250-260

34 Sheikh, Wahidul "Retaining competitive advantage in ship recycling under the new regulatory framework: a case study of Bangladesh" (2021)

35 Pastorelli, Silvia "EU Ship Recycling Regulation: What's in it for South Asia" : *European Institute for Asian Studies* (2014)

See Also: Sahu, Geetanjoy "Workers of alang-sosiya: a Survey of working conditions in a ship-breaking yard, 1983-2013" Economic and Political Weekly (2014): 52-59

36 Hossain, Khandakar Akhter "Overview of ship recycling industry of Bangladesh" *Journal of Environmental & Analytical Toxicology 5*, no. 5 (2015): 1-7

See Also: Du, Zunfeng, Haiming Zhu, Qingji Zhou, and Yiik Diew Wong "Challenges and solutions for ship recycling in China" Ocean Engineering 137 (2017): 429-439

37 Sunaryo, Sunaryo, Eko Djatmiko, Siti Fariya, Rafet Kurt, and Sefer Gunbeyaz "A gap analysis of ship-recycling practices in Indonesia" *Recycling 6*, no 3 (2021): 48

38 Knapp, Sabine, Shashi Kumar, and Anna Bobo-Remijn The ship recycling conundrum: an econometric analysis of market dynamics and industry trends No EI 2007-52. 2007

39 NGO Shipbreaking Platform "Quarterly Update Archives" NGO Shipbreaking Platform, 2022 https://shipbreakingplatform.org/tag/quarterly-update

40 Sheikh, Wahidul "Retaining competitive advantage in ship recycling under the new regulatory framework: a case study of Bangladesh" (2021)

41 Alcaidea, Juan Ignacio, Francisco Piniella, and Emilio Rodríguez-Díaza "The "Mirror Flags": Ship registration in globalised ship breaking industry" Transportation Research Part D: Transport and Environment 48 (2016): 378-392

42 European Commission. "Financial Instrument to Facilitate Safe and Sound Ship Recycling Final Report," 2016 https://ec.europa.eu/environment/pdf/waste/ships/financial_instrument_ship_recycling.pdf

43 Knapp, Sabine, Shashi Kumar, and Anna Bobo-Remijn The ship recycling conundrum: an econometric analysis of market dynamics and industry trends No EI 2007-52. 2007

44 Jain, Kanu Priya, J FJ Pruyn, and J J Hopman "Critical analysis of the Hong Kong international convention on ship recyclin" *International Journal of Environmental and Ecological Engineering 7*, No 10 (2013): 684-692

See Also: Ahmed, Ishtiaque "Ungovernable Ships at the End of Their Lives and the Response of the Hong Kong Convention: A Critical Appraisal of the Treaty on Ship-Breaking from the Perspective of South Asian Ship-Breaking Nations" *Santa Clara J. Int'l L.* 18 (2020): 124

45 Mishra, Shreya "Non-entry into force of the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships, 2009: An analysis from the perspective of India, Pakistan and Bangladesh." *Journal of International Maritime Safety, Environmental Affairs, and Shipping 2*, no. 1 (2018): 22-30

46 IMO. Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships, 2009, in International Conference on the Safe and Environmentally Sound Recycling of Ships, (2009): Hong Kong

47 Mikelis, Nikos. The Recycling of Ships. 1st ed., 2018

48 Jain, Kanu Priya, J. F. J. Pruyn, and J. J. Hopman. "Critical analysis of the Hong Kong international convention on ship recycling." *International Journal of Environmental and Ecological Engineering 7*, No. 10 (2013): 684-692

See Also: Mathew, Emil. "The Recycling of Ships Act 2019: Prospects for a Sustainable Ship Recycling in India." In OCEANS 2022-Chennai, pp. 1-4. IEEE, 2022

49 Pelsy, Florent. "The blue lady case and the international issue of ship dismantling." *Law Env't & Dev. J*. 4 (2008): 135

50 Ahmad, Mazyar. "Ship recycling in India-environmental stock taking." *Indian Law Review 6*, no. 3 (2022): 465-478

51 Nair, Avinash "Ship Recycling in Alang: What Is Its Capacity, and Can It Attract More Ageing Ships from Europe & Japan?" *The Indian Express*, 4 February 2021, Accessed indianexpresscom/article/explained/ship-recycling-alang-capacity-ageing-ships-europe-japan-7174436/. 25 January 2024

See Also: The Economic Times "Budget 2021: Ship Recycling Capacity to Double by 2024, Generate 1.5 Lakh Jobs." *The Economic Times*, 1 February 2021, economictimes.indiatimes.com/industry/transportation/shipping-/-transport/ship-recycling-capacity-to-double-by-2024-generate-1-5-lakh-jobs/articleshow/80629751.cms?from=mdr

52 Knapp, Sabine, Shashi Kumar, and Anna Bobo-Remijn The ship recycling conundrum: an econometric analysis of market dynamics and industry trends. No. EI 2007-52. 2007

53 NGO Shipbreaking Platform, "Shipping Industry's Disgrace: 85% of Global Tonnage Scrapped on Three Beaches in South Asia" 1 February, 2024 https://shipbreakingplatform.org/platform-publishes-list-2023/

54 Sheikh, Wahidul "Retaining competitive advantage in ship recycling under the new regulatory framework: a case study of Bangladesh" (2021)

55 Alcaidea, Juan Ignacio, Francisco Piniella, and Emilio Rodríguez-Díaza "The "Mirror Flags": Ship registration in globalised ship breaking industry" *Transportation Research Part D: Transport and Environment 48* (2016): 378-392

56 European Commission "Financial Instrument to Facilitate Safe and Sound Ship Recycling Final Report," 2016

57 Government of India| India Code. "The Recycling of Ships Act, 2019," 2019. https://www.indiacode.nic.in/handle/123456789/15690?view_type=browse&sam_handle=123456789/1362#:~:text=India%20Code%3A%20Recycling%20of%20Ships%20Act%2C%20

2019&text=Long%20Title%3A,connected%20therewith%20or%20incidental%20thereto

58 Mathew, Emil. "Ship recycling, market imperfections and the relevance of a consortium of ship recycling nations in the Indian subcontinent" *Journal of International Maritime Safety, Environmental Affairs, and Shipping* 5, no 2 (2021): 23-31

59 UNCTAD "Review of Maritime Transport 2021" UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT, 2021 https://unctad.org/system/files/official-document/rmt2021_en_0.pdf

60 NGO Shipbreaking Platform "Quarterly Update Archives" NGO Shipbreaking Platform, 2022 https://shipbreakingplatform.org/tag/quarterly-update

61 Manoj, P. "Lack of Oxygen Supply Set to Halt Ship Recycling at Alang" *BusinessLine*, 19 April, 2021 https://www.thehindubusinessline.com/economy/logistics/lack-of-oxygen-supply-set-to-halt-ship-recycling-at-alang/article34358794.ece

62 Srivastava, Ayushi, and Commodore Debesh Lahiri "Sustainable Ship Recycling In India– Social, Technological And Environmental Analysis" *National Maritime Foundation*, 20 Feb 2024, maritimeindia.org/sustainable-ship-recycling-in-india-social-technological-and-environ mental-analysis/.

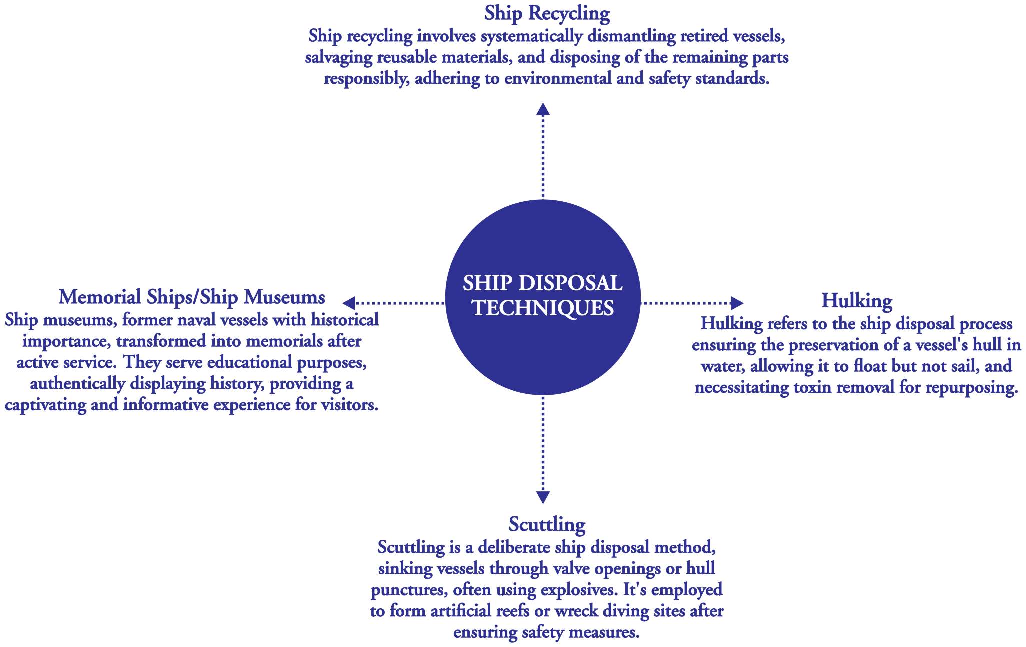
Sustainable Ship Recycling In India – Social, Technological And Environmental Analysis

Ms Ayushi Srivastava and Commodore Debesh Lahiri (Retd)

In the intricate tapestry of global trade, the shipping industry emerges as a vital component, facilitating the movement of goods across seas that form the arteries of our interconnected world.[1] With ships typically boasting a lifespan of 25-30 years, the question of their disposal becomes a critical decision point where economic considerations need to be balanced *vis-a-vis* environmental responsibility.[2] Post their operational life, a significant number of vessels find their way to ship-breaking yards, transforming into inventories of steel, iron, and other valuable resources. The challenge of environmentally safe disposal of the end-of-life (EOL) ships becomes particularly pronounced in a globalized world, where the world trade fleet assumes a pivotal role in curbing transport costs.[3] Addressing the issue of EOL vessels demands responsible disposal methods, where scuttling of vessels in the open oceans should be the last resort.[4] The array of alternative options available encompasses vessel reuse or land-based recycling or repurposing for use as an artificial reef.[5] The principles established by the United States Environmental Protection Agency's Marine Protection, Research, and Sanctuaries Act (US EPA-MPRSA) can serve as a guiding framework in navigating these choices.[6] The above act reinforces the importance of prioritizing a balanced and sustainable approach, with a particular emphasis on land-based disposal methods such as ship recycling. The MPRSA underscores the significance of ecosystem preservation during ship disposal, marking a notable shift towards a heightened awareness of responsible practices that aim to shield marine environments from potential adverse effects.[7]

While the ship breaking industry was predominantly concentrated in Europe and the United States before the 1970s, a notable shift occurred thereafter as it migrated

Figure 1. Common Ship Disposal Techniques



Source: Collated by the authors

to regions with more lenient legal frameworks.[8] This transition was spurred by the imposition of stricter social and environmental protection laws in the Global North, raising concerns about the standards being followed in ship recycling yards.[9] Currently, South Asia has emerged as the epicentre for the ship-breaking industry, with Bangladesh, India, and Pakistan garnering an overwhelming majority of ship recycling orders.[10] Despite initial apprehensions about environmental damage, there is a glimmer of optimism in recognizing ship recycling as the optimal way to retire vessels.[11] This approach involves repurposing and recycling approximately 90% of the materials, presenting an efficient method that not only saves resources but also aligns with sustainable practices.[12] As surprising as it may seem, the ship-breaking industry, often viewed with scepticism, holds the potential to transform into an environmentally friendly enterprise.[13] A case in point is Alang in Gujarat, India, where a transition towards sustainable ship recycling practices is underway, showcasing the possibility of converting what was once a serious environmental concern into a beacon of environmental responsibility.

The International Maritime Organization (IMO) has also played a pivotal role in addressing ship recycling concerns since the 44th Marine Environmental Protection Committee (MEPC) session in 2000. Initiated by a correspondence group, the IMO developed Guidelines on Ship Recycling, and adopted it in 2003, advising stakeholders worldwide. Recognizing the urgency of incorporating environmentally friendly guidelines in ship recycling the MEPC 53 in 2005 prioritized a legally binding instrument on ship recycling, emphasizing safety, environmental sustainability, and an enforcement mechanism. This led to the development of the Hong Kong Convention (HKC), adopted in 2009 after collaborative efforts. The convention signifies IMO's commitment to minimizing environmental and safety risks, ensuring sustainable ship recycling practices, and addressing the unique challenges of the world maritime transport system.[14] The HKC enters into force on June 26, 2025.[15]

India's Dynamic Ship Recycling Landscape

India stands as the world's second-largest player in the ship recycling industry, only behind Bangladesh.[16] The focal point of India's ship recycling prowess is the Alang Sosiya Ship Recycling Yard (ASSRY) in Gujarat, a coastal stretch in the Bhavnagar district spanning more than 10 kilometres.[17] Alang commands a staggering 98% of India's ship recycling capacity and significantly contributes 32.6% to the global recycling volume.[18] However, despite its abundant potential, the current state of affairs at Alang reveals a surprising statistic — 48% of its existing ship-breaking capacity remains idle.[19]

The ASSRY consists of 153 plots, with 131 plots currently being utilised for shipbreaking activities with the balance of 22 plots in disuse pending litigation. However, only 80 of these 131 plots are presently operational, hinting at an untapped potential waiting to be harnessed. This under-utilization contrasts with the industry's peak year in 2011-12 when 415 ships, totalling 3.85 million Light Displacement Tonnage (LDT), flocked to Alang. This period was the zenith, with shipbreaking activities almost reaching the full capacity of 4.5 million LDT. Subsequently, a decline ensued, exemplified by the fiscal year 2019-2020, witnessing only 202 ships with 1.62 million LDT. The fiscal year 2020-2021, until January 2021, showed a modest improvement with 199 ships and 1.8 million LDT.[20]

Figure 2. Google Earth View of Alang Sosiya Ship Recycling Yard (ASSRY)

Source: Google Earth[21]

In a bid to fortify its position in the global ship recycling landscape, India has ambitious plans to augment its recycling capacity up to 9 million LDT.[22] The industry currently provides gainful employment to a substantial workforce of 5.15 lakh people. Notably, over the last five years, the ship recycling sector has contributed an average revenue of 55 Crores per annum, emphasising its economic significance and sustained growth potential.[23] The ship recycling activities in India are also conducted in a limited manner at the Kidderpore Docks, Syama Prasad Mookerjee Port, Kolkata; the Mumbai Port, and by the Steel Industrials Kerala Limited.[24]

The ship recycling sector at Alang is emerging as a pivotal player, skilfully navigating the delicate balance between economic advancement and environmental sustainability. Alang's significance extends beyond its contribution to the global ship recycling industry; it plays a crucial role in generating approximately 3.50 million

Metric Tonnes (MMT) of steel annually, producing substantial quantities of re-rollable steel without depleting natural resources or triggering the environmental impacts associated with traditional steel production processes, such as mining, energy consumption, water usage, and toxic effluents. The potential to produce re-rolled steel positions Alang as a green route for generating secondary steel, offering a sustainable alternative to extracting steel from Iron ore. A comparison between the resource requirements for producing 4 million tonnes (Mt) of steel through the conventional route and ship recycling route is illustrated in the accompanying Table 1 to drive home the environmental advantages and sustainability inherent in Alang's ship recycling practices.

Table 1. Resource Requirements for Producing 4 Mt Steel by Conventional Route and by Ship Recycling Route Source: Environmental Impact Assessment and Environmental Management Plan[25]

Sl No	Natural Resources	Steel Plant	Ship Recycling Industry	Saving in Ship Recycling
1	Iron Ore (t)	7,000,000	0	7,000,000
2	Refractory materials / additives (t)	2,800,000	0	2,800,000
3	Coal (t)	6,200,000	0	6,200,000
4	Process Chemicals (t)	160,000	0	160,000
5	Oxygen (Nm^3)	260×10^6	72×10^6	188×10^6
6	Water (Million m^3)	100 – 240	0.80	99.2 – 239.2
7	Fuel Oil (t)	120,000	220,000	-100,000
8	LPG (t)	0	16,000	-16,000
9	Energy (as fuel and electricity) (J)	80,000 x 1012*	80,000 x 1012	0

t – tonnes

Nm^3 – Normal cubic meters. The 'Normal' refers to normal conditions of 0 degrees Celsius and 1 atm (standard atmosphere = 101.325 kPa) – for particle purposes this is rounded to 1 bar

J – Joules

* Does not include energy required for transport of raw materials to plant site

According to the Gujarat Maritime Board, a comparison of natural resource consumption in the production of 2 million tonnes of steel through a steel plant and ship recycling reveals significant savings in the latter in two key aspects. Firstly, in terms of solid waste, the steel plant generates approximately 878,967 tonnes, while the ship recycling industry produces only 12,500 tonnes, resulting in a substantial total saving of 866,467 tonnes of solid waste or a savings of 433234 tonnes of solid waste per tonne of steel produced. Secondly, the steel plant incurs a total cost exceeding ₹1000 crore, whereas the ship recycling industry's total expenses are less than ₹100 crore, culminating in an overall saving of around ₹900 crore or a saving of ₹450 crores per tonne of steel produced.[26]

Additionally, ASSRY, with an existing ship recycling capacity of about 4.5 million tonnes per annum, has the potential to reduce annual CO_2 emissions by 7.34 million tonnes compared to conventional steel production from iron ore.[27] It is therefore evident that responsible ship recycling is a sustainable route towards India becoming more environmentally conscious and contributing to the reduction of greenhouse gas emissions, in alignment with India's net-zero emissions target by 2070.[28] With more than 100 recycling plots adhering to the Hong Kong Convention standards, Alang stands as a beacon of environmentally responsible ship recycling.[29]

While there are numerous advantages to undertaking ship recycling in India, the country must address significant challenges within the Indian Ship Recycling Sector. These challenges, extensively discussed in the first segment of this two-part series on sustainable ship recycling — an outcome of the "Sustainable Ship Recycling in India" project by Team NMF — are diverse and complex, impacting the sector's overall operation and growth trajectory.[30] A key challenge involves the industry grappling with enhanced legal and administrative costs incurred to comply with Health, Safety, and Environment (HSE) regulations.[31] The necessity to meet rigorous regulatory standards requires substantial investments to ensure worker safety and environmental protection, thereby adding a considerable financial burden to the sector. Consequently, there is a pressing need for comprehensive policy reforms, strategic planning, and collaborative efforts to address regulatory, operational, and financial constraints collectively. Successfully overcoming these obstacles is crucial for the Indian ship recycling sector to thrive, contribute sustainably to the economy, and establish itself as a global player in the ship recycling industry.

Alang: India's Hub for Ship Recycling

Alang, having evolved into the central hub for shipbreaking activities now known as recycling, is a testament to India's dedication to maritime endeavours and environmentally responsible practices. The Gujarat Maritime Board (GMB) after a thorough survey of the coastal region, ultimately designated Alang as the most suitable site for developing shipbreaking operations.[32] Both the GMB and other interested stakeholders endorsed this selection based on key factors highlighted in the first part of this two-part article.

The site's strategic positioning within the high tide zone and ideal weather conditions supports continuous ship breaking operations. Additionally, Alang boasts other favourable conditions viz., the seabed's quick drying capability, even during monsoons, which facilitates the handling of various materials and equipment involved in the ship breaking process; the sloping coast of Alang, along with a long dry area, facilitates the uninterrupted beaching of vessels, thereby enhancing the overall handling of EOL vessels. Moreover, the coastal area of Alang is strategically devoid of other competitive users, such as merchant shipping, fishing, and salt pans.[33] This unique combination of geographic advantages has catapulted the ASSRY as a major player in the ship recycling industry. It not only highlights India's commitment to sustainable maritime practices but also emphasizes the crucial role ASSRY plays in fulfilling the escalating demand for steel while adhering to responsible environmental practices. In essence, ASSRY emerges as an invaluable asset for India's ship recycling industry.[34]

Figure 3. Bhavnagar anchorage area

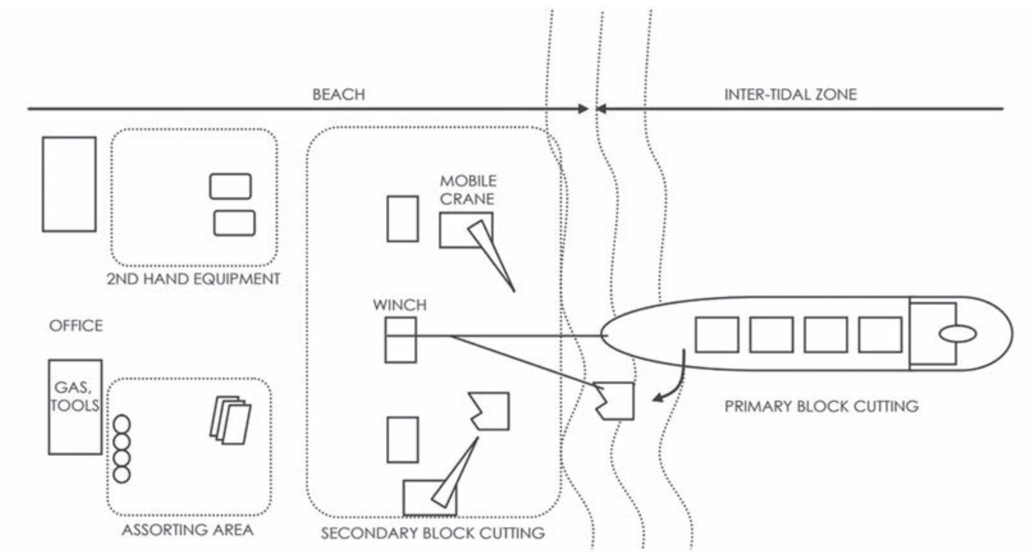
Source: Captured by authors during the visit

Upon entering the Indian Maritime Zone for ship recycling, vessels must notify both the Maritime Rescue Co-ordination Centre (MRCC) and the Indian Coast Guard regarding their intended destination at ASSRY. Subsequently, the vessel seeks permission to drop anchor, a step facilitated following a thorough desk review conducted by the Port Authority, Gujarat Maritime Board (GMB), and Customs.[35] The detailed process is already explained in the first part of the duology under the heading "Ship Recycling Step-by-Step Procedure." The comprehensive ship recycling cycle, spanning inspection, preparation, and certification, ultimately culminates in the recycling of the ship's steel and other reusable products.[36]

Once a vessel enters a ship recycling yard, it undergoes a planned series of steps, starting with the critical process of beaching. During this phase, the ship is intentionally grounded in shallow water, rendering it immobile and irreversible.[37] A typical beaching scenario in Alang is illustrated in Figure 4.

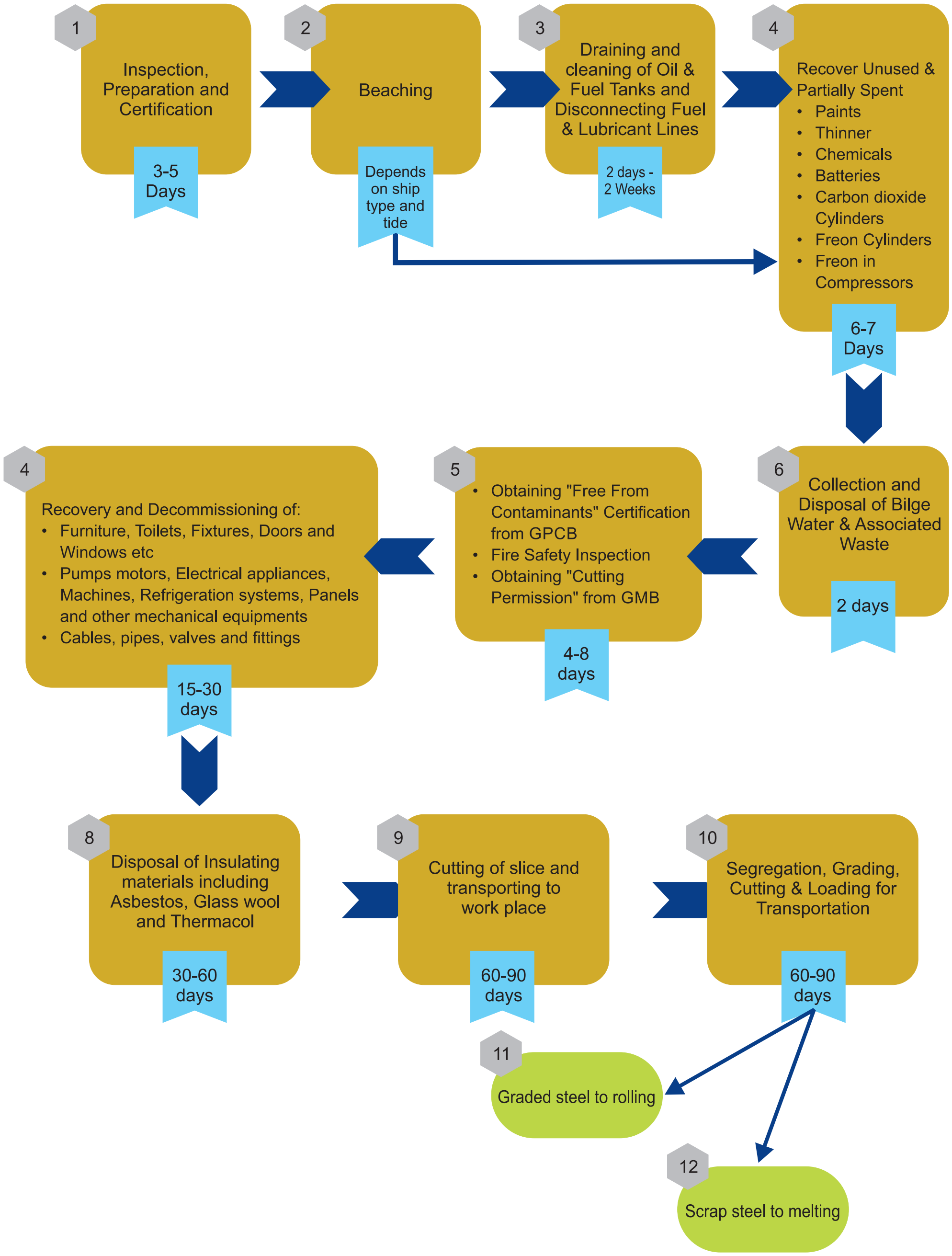
The duration for entire ship recycling process varies, ranging from 3.5 to 9 months, contingent upon factors such as the vessel's size and type. Despite the specific recycling plans and procedures of each yard, a common and time-tested tacit

Figure 4. Typical Beaching in Alang



Source: Arya Steel Handbook[38]

Figure 5. Typical Ship Recycling Procedure



Source: Collated by Authors

know-how prevails in Alang, as depicted in Figure 5, illustrating the "typical ship recycling procedure." This standardized approach ensures economic, procedural, environmental, and work-safety advantages, with each work activity's duration and input-output meticulously outlined for efficient execution.

The representatives of the European Union and the media continue to highlight serious concerns in ASSRY with respect to pollution in the intertidal area; the absence of medical facilities; breaches of labour rights; and challenges in managing hazardous waste streams including mercury and radioactive contaminated materials commonly found in offshore oil and gas units. The resale of asbestos-contaminated materials in India and the absence of a proper disposal site for PCBs further contribute to the negative perception of Alang-Sosiya.[39] However, a closer examination of the ASSRY reveals noteworthy progress compared to the previous decade. Out of the total 153 plots, approximately 103 are procedurally compliant with the Hong Kong Convention (HKC), and about 27 yards are actively striving for compliance with the European Union Ship Recycling Regulations (EUSRR). Recent efforts by the authorities has resulted in a more positive impact on the safety and well-being of workers and the environment, showcasing a commitment towards addressing the previously identified concerns. These ongoing efforts are indicative of a proactive approach to enhance sustainability and compliance within the ship recycling industry in Alang.

SOCIAL PERSPECTIVE

Workers Training and Safety

Amidst concerns raised by organisations regarding worker safety and training in Alang, interactions with the workers at the Safety Training and Labour Welfare Institute reveal a starkly contrasting reality. The institute, operating in Alang, has demonstrated significant success in reducing accidents through its rigorous training programs. Notably, the reported fatalities resulting from yard accidents have been limited to eleven between 2020 and 2023, showcasing the tangible impact of safety initiatives. The comprehensive approach to safety is amply evident in the assignment of a dedicated Safety Officer to each recycling plot, supported by one or more safety

Figure 6. Safety Training and Labour Welfare Institute

Source: Pictures taken during the interaction of Team NMF with the trainees at the institute.

supervisors. Moreover, the office of the Gujarat Maritime Board (GMB) at Bhavnagar has a Safety Department staffed with qualified Safety Officers, emphasizing a systemic approach towards ensuring worker safety.

Table 2. Accident Data of ASSRY

Accident Data													
Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
No. of Fatal	5	15	9	18	4	7	8	12	1	0	2	8	1

Source: Data provided by ASSRY Authorities

Since its establishment in 2003, the Safety Training and Labour Welfare Institute has enjoyed the unwavering support of the Gujarat Maritime Board, resulting in the proficient training of 1,56,503 skilled professionals. The training program, comprising mandatory 12-day comprehensive safety training, an intensive 2-day gas cutter safety training customized for gas cutting activities, and a comprehensive 3-day refresher safety training for personnel with prior training, underscores a commitment to empowering workers with the necessary skill-sets for their tasks. Additionally, the institute conducts seminars at regular periodicities addressing pertinent subjects to meet the distinct requirements of individual yards.

In line with their commitment towards the welfare of workers, Alang authorities have constructed seven residential blocks, providing well-designed accommodations for a total of 1008 workers. These initiatives reflect a proactive stance towards enhancing the comfort and safety of workers, challenging the negative perception propagated by external vested entities. The water supply to ASSRY is facilitated through a pipeline connected to the Gujarat Water Supply Board. The capacity of the clean water supply system is 3 million litres per day, which comfortably exceeds the daily requirement ranging from 1.6 to 1.8 million litres. As a result, there is generally no issue with water supply. However, occasional shortages may arise during the summer months. In such cases, additional fresh water is supplied through tankers to ensure that the balance requirement is adequately met.[40]

Figure 7. Multi-specialty hospital and Accommodation Block

Source: Pictures taken during the visit of Team NMF to Accommodation block and multi-specialty hospital

Medical Facilities

Significant strides have been made in improving the medical facilities in Alang, addressing concerns and enhancing the overall well-being of the workforce. Presently, three medical facilities operate in the area — a multi-specialty hospital, a primary hospital, and a mobile health unit — all managed jointly by the Indian Red Cross Society and the Gujarat Maritime Board. These facilities are equipped to handle routine medical care, attend to minor injuries, perform surgeries, and provide immediate relief in the event of significant accidents. The expenses associated with medical treatment are covered by the plot owner where the injured worker was employed, emphasizing a collaborative approach to worker health. Complementing these efforts, the Ship Recycling Industries Association (SRIA) is at an advanced stage of establishing a Trauma Centre, Health Care Centre, and Welfare Centre dedicated to Alang's workforce. Furthermore, the Gujarat Maritime Board is converting a building owned by the Justice Dewan Charitable Trust into a comprehensive hospital specifically catering to ASSRY workers, with SRIA covering all associated costs. To promote occupational health awareness, the GMB's Training Centre, SRIA's medical professionals, along with external experts, conduct informative campaigns, demonstrating a holistic commitment to improving and expanding medical facilities in Alang.

Technological Perspective

Alang has made significant strides in improving its ship recycling infrastructure and technology, introducing innovative measures to enhance safety and environmental sustainability within the ship recycling industry. The integration of liquid oxygen in the yards has streamlined gas cutting processes, providing a more efficient and controlled approach. Moreover, the strategic plans to transition towards plasma and water-jet cutting technologies in the coming years stresses the industry's commitment towards embracing advanced environment-friendly technological capabilities. Another noteworthy development is the incorporation of geo-membrane layers in a majority of the yards. Comprising impermeable geosynthetic material, these layers act as a robust barrier, preventing the seepage of harmful contaminants and

Figure 8. Geo-membrane layer on the yard and Liquid Oxygen supply tank in a yard

Source: Pictures taken during the visit of Team NMF to ship recycling yards

hazardous chemicals into the soil. This proactive measure not only safeguards the soil from potential hazards but also demonstrates a conscientious effort to mitigate environmental impact.

Environmental Perspective

In the pursuit of sustainable ship recycling, Mecon Limited conducted a comprehensive environmental assessment survey focusing on air and water quality, noise levels, and ecological impact in the Alang region. The ambient air quality at five distinct locations, including Alang village and Sosiya village, was diligently monitored for Particulate Matter (PM10 and PM2.5), Sulphur dioxide (SO_2), and Oxides of Nitrogen (NOx). The results of the survey spanning a twelve-week period, revealed that the ambient air quality parameters in the villages adhered to the National Ambient Air Quality Standards, 2009 for "Industrial, Residential, Rural, and Other Areas." Work zone air quality within ship breaking plots and the

Alang Waste Treatment Storage Disposal Facility (TSDF) met the stipulated norms outlined by the Indian Factories Act.[41] Water quality monitoring covered sea water, Pasvivali Creek, ground water, and effluents from ships and the Alang TSDF. Sea and creek water analysis indicated levels within limits stipulated in the "Primary Water Quality Criteria for Coastal Waters," while ground water from Alang and Mathavda villages was deemed unsuitable for drinking. In terms of noise pollution, continuous monitoring at Alang Fire Station and surrounding villages demonstrated that average noise levels met the standards for Residential and Industrial Areas prescribed by the Central Pollution Control Board.[42]

The ecological study revealed a semi-arid landscape with sparse vegetation dominated by Prosopis juliflora (Gando-baval) and a limited variety of land animals. In addition to the absence of ecologically sensitive areas and mangroves, the study identified presence of common bird species but reported low biodiversity and biomass of marine life in the Alang area, with no commercial fishing activities.[43] Overall, this comprehensive environmental analysis, conducted by Mecon Limited and observed by the authors through engagement with stakeholders and authorities, forms a crucial foundation for ensuring responsible and sustainable ship recycling practices in the region.

Method of Identification, Removal and Disposal of Hazardous Inventory

a. **Asbestos** is normally found in insulation areas like bulk head, pipe insulation, cold or hot areas needing insulation in machinery and engine room spaces. Ceilings are also often found containing asbestos in ships. Removal of asbestos is done in a negative pressure area wherever required. Special signage is used on vessels and on bags during compilation of the Inventory of Hazardous Material (IHM) for identification of items containing asbestos on ship. Green Gene Enviro Protection and Infrastructure Private Limited (GGEPIL) approved by the Gujarat Pollution Control Board (GPCB) is contractually authorised to handle, transport and dispose materials in accordance with laid down regulations from hazardous material storage to GGEPIL's processing plant. It bears mention that the quantum of asbestos being used on ships is constantly decreasing and most ship designs are aiming to be asbestos-free.

b. **Paints** used on vessels in 70s and 80s used to contain asbestos and Tributyltin (TBT). In case, scrutiny of the IHM or available vessel data reveals that the paints used onboard the vessel contain any of the hazardous ingredients, then the paint chips are removed with utmost care by chipping method. Special signage is used on vessel for bags containing paint chips which is sent to the Treatment, Storage and Disposal Facility (TSDF) / GGEPIL in Alang.

c. **Oily Sand and Oily Rags** are generated during cleaning of different types of tanks and spaces of vessels during the entire ship recycling process. The sand used for cleaning oily tanks is resultantly contaminated with oil contents which makes it hazardous in nature. Oily rags used for cleaning cannot be reused in any way. The oily sand and rags are collected in bags and disposed to the TSDF/GGEPIL site with special signage being used on bags containing oily sand and rags.

d. **Bilge Water** is normally removed by pumping out facility at ports but some bilge water remains on the vessel during beaching and is required to be pumped out by yard resources and sent to TSDF /GGEPIL located in Alang. Bilge water records are maintained onboard the vessel being recycled. Special signage is used for tanks containing bilge water in the yard.

e. Many usable **batteries** are recovered from the vessels being recycled and are reused in the yard utility equipments such as cranes and winches. **Batteries that are found unusable** are collected and sent for disposal to the TSDF / GGEPIL site.

f. **Rubber and plastic items** are collected in the non-hazardous storage area of the yard. Both materials are collected in bags with special signage for identification and are disposed to TSDF / GGEPIL in Alang on periodic basis.

g. **Glass wool** is used in insulation onboard vessels like asbestos and normally is white or yellow in colour. The glass wool is collected in bags with special signage for identification and is disposed to TSDF / GGEPIL in Alang on periodic basis.

h. **Cement and ceramic waste** are collected in non-hazardous waste storage rooms in the yard in bags and then sent to the TSDF site / GGEPIL on periodic basis.

From Challenges to Opportunities

In specific reference to ship recycling and India's evolving maritime practices, Gujarat Chief Minister, Shri Bhupendra Patel, made a significant announcement at an International Seminar on Ship Recycling and Vehicle Scrap Policy in September 2022 at Gandhinagar. Drawing attention to Gujarat's extensive coastline and maritime heritage, he underscored the state's pivotal role in India's port-led development. The Chief Minister specifically addressed the burgeoning field of ship recycling, accentuating a transition towards green practices. He stated that this transformation aligns with the vision set forth by the government of India through the enactment of the Recycling of Ships Act, 2019 and reiterated Gujarat's aspiration to position Alang as a leading green ship recycling hub, showcasing India's commitment to environmentally friendly practices while invigorating the ship recycling industry. The event served as a testament to Gujarat's integral role in India's economic development, shedding light on advancements in ship recycling and the broader maritime sector.[44]

Continuing the narrative on India's ambitious plans for the ship recycling industry, the government's forward-looking document, Maritime Amrit Kaal Vision 2047, extends the trajectory defined by the Maritime India Vision 2030 (MIV 2023). The 2047 vision outlines a timeline and the collaborative efforts required from various stakeholders to address the major challenges confronting the Indian Ship Recycling Industry. The focused efforts outlined in Maritime Amrit Kaal Vision 2047 and enumerated in the table below represent a proactive approach to transform challenges into opportunities and position India as a global hub for environmentally sustainable ship recycling practices.

Table 4. Action Plan of the Indian Government for the Ship Recycling Sector.

Sl No.	Issues/ Challenges	Present status	Proposed Consideration	Action Plan for Implementation	Timeline
1	Underutilization of the available infrastructure, of the 153 plots in Alang, 131 have been allotted and 22 are vacant. Approximately 48 percent under-utilization of working plots handling an average 2 MMTPA of LDT.	Resize the plots in ASSRY and create an extra recycling cluster on the East Coast of India to bolster ship recycling infrastructure under the MIV 2030 initiative.	Enhancement of existing utilized capacity of 2 Million Metric Tonnes Per Annum (MMTPA) (131 plots) at ASSRY to 5.24 MMTPA	• Relaxation in Annual fixed Charges • Amendment in Constitution changes of plot holder • Transfer of Plots	Q4, 2023
				Adding 22 plots to enhance capacity to 0.88 MMTPA • Auction of 8 plots as directed by the Honourable Supreme Court of India • Amendments in Reservation Policy in a non-arbitrary manner, as directed by the Honourable Supreme Court of India Auction of 14 plots	Q3, 2025
				Adding 15 plots to enhance capacity to 1.20 MMTPA Coastal Regulatory Zone (CRZ) Clearance, Land Acquisition and Extension of road. Adding 30 plots to enhance capacity to 2.40 MMTPA CRZ Clearance, Land Acquisition and Project Management Consultant (PMC) Finalization	Q3, 2025
2	Higher Taxes	Import Duty 2.5% and GST 18% being levied.	Reduction in tax rate in line with imported baled scrap	Detailed study to arrive at revised tax rates	Q4, 2023
				Ministry of Ports, Shipping and Waterways (MoPSW) to send representation to Income Tax department	Q4, 2023
				Approval from Income Tax department	Q1, 2024
3	Overcoming the BIS Non-Recognition Barrier: Exploring Solutions for the Integration of Recycled Steel in Diverse Sectors, with a Focus	BIS not recognizing recycled Steel. Projects already identified under the initiative: - (Source: MIV 2030) Modification of	Amend BIS Regulation (IS 1768:2008) for Thermo Mechanically Treated steel (TMT) bar production to permit the use of ship scrap, focusing on material	Proposal to Bureau of Indian Standards (BIS) based on detailed study	Q4, 2023

	on the Real Estate Industry	BIS regulations (IS 1786:2008) governing TMT bar production to allow usage of ship scrap basis material composition and strength/ quality in place of existing requirement of metallurgical history	composition, strength, and quality, as an alternative to the current metallurgical history requirement	Approval from BIS	Q4, 2023
4	Limited Ship Recycling Clusters	Development of other ship recycling clusters	Development of other ship recycling clusters at West Bengal and Visakhapatnam	Conduct a comprehensive location study encompassing strategy, business model, finance, taxation, commerce, industry, policy law, foreign trade, etc., to finalize destinations	Q4, 2023
				Prepare and submit a proposal to the MoPSW with the rationale, tentative budget, and suggested action for approval	Q4, 2023
				Land acquisition and CRZ clearance	Q4, 2024
				Issue Request for Proposal (RFP) for development of ship recycling clusters with suitable business Model	Q1, 2025
				Development of facility	Q4, 2026
5	Limited Marketability of ship byproducts and lack of transparency	Collaborate with other countries through MEA to establish a ship recycling facilitation centre, promoting recycling activities and enhancing marketability of ship by-products via trade fairs at ship breaking yards, involving stakeholders from shipowners to downstream industries, as identified under the MIV 2030 initiative	Intervention of MEA, Government of India with European Union, OECD countries for sending their vessels directly to ASSRY without routing through Flag of Convenience (FOC) with subsidized selling price like Turkey. MEA may also intervene with EU countries to send their vessels to Alang at subsidized rates considering HKC compliance status	Detailed study to arrive at subsidised rates in line with international bodies	Q4, 2023
				Proposal to Ministry of External Affairs (MEA) to collaborate with countries to send their vessels directly to Alang without routing through FOC with subsidized selling price	Q4, 2023
				Approval from MEA	Q2, 2024

Source: Maritime Amrit Kaal Vision 2047, Maritime India Vision 2030 and through interactions of Authors with stakeholders[45,46]

Recommendations

The ship recycling industry in Alang has witnessed positive changes in recent years, yet challenges persist, especially in environmental and safety aspects. To foster further improvement and sustainability, the following recommendations are proposed:

Promotion of India's Ship Recycling Sector:

- Organize annual seminars to promote sustainable ship recycling, emphasizing benefits and solutions.
- Improve transparency to enhance the industry's global image and showcase Alang's development.

Inspection and Worker Rights:

- Increase administrative and financial capacity for regular inspections.[47]
- Establish a comprehensive database on migrant workers with regular updates.[48]
- Provide detailed education on workers' rights under labour laws.

Environmental Monitoring and Transparency:

- Develop a transparent environmental monitoring system.
- Conduct a GAP analysis to identify areas for improvement in medical facilities and waste management.

Enhanced Drainage System and Cutting Methods:

- Address the effectiveness of the drainage system in the secondary cutting zone.
- Examine alternative cutting methods, especially water jet cutting to minimize risks.[49]

Sustainable Coat-Stripping Techniques:

- Explore sustainable coat-stripping methods, such as dry ice blasting, to reduce emissions of hazardous pollutants.[50]
- Investigate the transition from traditional sand blasting to environmentally friendly alternatives.

Circular Economy Transition:[51]

- Work towards transitioning ship recycling into a circular economy.
- Implement circular economy policies for improved scrap steel availability.
- Utilize optical recognition and artificial intelligence for precise scrap quality assessment.

These recommendations encompass short-, medium-, and long-term strategies aimed at addressing immediate concerns while fostering the long-term sustainability of Alang's ship recycling industry. The implementation of these measures will contribute to enhancing environmental practices, worker safety, and the overall reputation of Alang on the global stage.

Conclusion

India's ship recycling industry, centred around the ASSRY, stands at a critical juncture where challenges and opportunities intersect. The historical shift of ship recycling activities from the Global North to South Asia, driven by stringent regulations, has positioned India as a key player in the sustainable disposal of End-of-Life vessels.[52] The economic and environmental advantages of responsible ship recycling, exemplified by the ASSRY, highlight the potential for India to become a global leader in this sector.

The challenges faced by the Indian ship recycling sector, including underutilization of plots, high compliance costs, tax burdens, demand a comprehensive approach for policy reforms and strategic planning. The significant strides made in Alang, especially in addressing concerns related to worker safety, environmental pollution, and regulatory compliance, reflect a positive trajectory. Recent developments, such as the commitment to green practices and the vision outlined in Maritime Amrit Kaal Vision 2047, further reinforce India's commitment to sustainable ship recycling practices.

The recommendations put forth, ranging from promoting India's ship recycling sector and capacity building to addressing environmental concerns and adopting circular economy principles, provide a roadmap for the industry's sustained growth. These recommendations, if implemented diligently, can contribute to enhancing Alang's global standing, ensuring responsible ship recycling practices, and aligning with India's aspirations for a green and economically robust maritime sector. The evolution of Alang from facing challenges to embracing opportunities symbolizes a commitment to environmental stewardship and responsible industry practices, setting the stage for India to become a beacon of environmental sustainability in the ship recycling landscape.

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ENDNOTES

1. R. Scott Frey, "Breaking Ships in the World-System: An Analysis of Two Ship Breaking Capitals, Alang India and Chittagong, Bangladesh", Tennessee Research and Creative Exchange (TRACE), University of Tennessee, Knoxville, May 2013. https://trace.tennessee.edu/cgi/viewcontent.cgi?article=1001&context=utk_cssjpapers

2 Md. Golam Mohiuddin et, "Analysis of Present Global Ship Recycling Status and Challenges for Bangladesh", Global Scientific Journals Volume 11, Issue 4, April 2023

3 *Ibid*

4 Disposal of Vessels at Sea, United States Environmental Protection Agency, accessed on 24 November 2023 https://www.epa.gov/ocean-dumping/disposal-vessels-sea

5 Soumyajit Dasgupta, "10 Types of Ship Disposal Techniques", Marine Insight, 02 April 2019. https://www.marineinsight.com/guidelines/10-types-of-ship-disposal-techniques/

6 Disposal of Vessels at Sea, United States Environmental Protection Agency, accessed on 24 November 2023, https://www.epa.gov/ocean-dumping/disposal-vessels-sea

7 *Ibid*

8 Ananya Mukherjee and Bhavna Shri Harsha, "Maritime Pollution and the Shipbreaking Industry — Challenges and Mitigation-Options", National Maritime Foundation, 05 April 2021, https://maritimeindia.org/maritime-pollution-and-the-shipbreaking-industry-challenges-and-mitigation-options/#_ftn5

9 *Ibid*

10 The Problem, NGO Shipbreaking Platform, accessed on 24 November 2023, https://shipbreakingplatform.org/our-work/the-problem/

11 Md. Golam Mohiuddin et al., "Analysis of Present Global Ship Recycling Status and Challenges for Bangladesh", *Global Scientific Journals* Volume 11, Issue 4, April 2023

12 *Ibid*

13 *Ibid*

14 Recycling of ships, International Maritime Organisation (IMO), accessed on 08 December 2023, https://www.imo.org/en/ourwork/environment/pages/ship-recycling.aspx

15 The Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships, International Maritime Organisation (IMO), accessed on 08 December

2023, https://www.imo.org/en/About/Conventions/Pages/The-Hong-Kong-International-Convention-for-the-Safe-and-Environmentally-Sound-Recycling-of-Ships.aspx

16 Maritime Amrit Kaal Vision 2047, Ministry of Ports, Shipping and Waterways (MoPSW), Government of India, October 2023, https://shipmin.gov.in/sites/default/files/Maritime%20Amrit%20Kaal%20Vision%202047%20%28MAKV%202047%29_compressed_0.pdf

17 Annual Report 2022-23, Ministry of Ports, Shipping and Waterways (MoPSW), Government of India, 2022-23, https://shipmin.gov.in/sites/default/files/Annual%20Report%202022-23%20English.pdf

18 Maritime Amrit Kaal Vision 2047, October 2023, Pg. 218

19 *Ibid*

20 *Ibid*

21 Google Earth, accessed on 14 December 2023, https://earth.google.com/web/search/Alang Sosiya+Ship+Recycling+Yard,+Alang,+Gujarat/@21.41210225,72.20119175,16.4660299a,6518.53108701d,35y,-0h,0t,0r/data=CigiJgokCSD9530eOjRAER_9530eOjTAGf6tGZ-npThAIbyWaVjrRVPAOgMKATA

22 Annual Report 2022-23, Pg. 50

23 Maritime Amrit Kaal Vision 2047, October 2023, Pg. 218

24 Annual Report 2022-23, Pg. 50

25 Environmental Impact Assessment and Environmental Management Plan, Proposed Upgradation of Existing Ship Recycling Yard at Alang Sosiya, Gujarat for Undertaking Safe and Environmentally Sound Ship Recycling Operations, Gujarat Maritime Board and Mecon Limited, July 2016, https://www.jica.go.jp/Resource/english/our_work/social_environmental/id/asia/south/india/c8h0vm00009ulddw-att/c8h0vm0000ahd7tr.pdf

26 Presentation on Alang Ship Breaking Yard, Gujarat Maritime Board (GMB), Government of Gujarat, accessed on 14 December 2023, https://www.imaritime.com/knowledgebase/test1.pdf

27 "Alang-Sosiya: The world's biggest ship recycling yard gears up for eco-friendly recycling", YouTube video, 9:05, "CMO Gujarat", September 2022, https://www.youtube.com/watch?v=0ZZHw-N42c4&t=1s

28 "Net zero emission target", Press Release, Ministry of Environment, Forest and Climate Change, Government of India, August 2023, https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1945472

29 *Ibid*

30 Ms Rhythma Kaul and Commodore Debesh Lahiri "Sustainable Ship Recycling in India-Legal, Economic and Political Analysis", National Maritime Foundation, January 2024

31 Maritime Amrit Kaal Vision 2047, October 2023, Pg. 218

32 Hrudanand Misra, "Analysis of Alang Ship Breaking Yard, India", Institute of Management, Nirma University, Ahmedabad, Gujarat, India, *Economic Affairs*, Vol. 64, No. 2, pg. 417-424, June 2019

33 *Ibid*

34 Environmental Impact Assessment and Environmental Management Plan, Pg. ES-1, https://www.jica.go.jp/Resource/english/our_work/social_environmental/id/asia/south/india/c8h0vm00009ulddw-att/c8h0vm0000ahd7tr.pdf

35 Environmental Impact Assessment and Environmental Management Plan, Pg. ES-1, https://www.jica.go.jp/Resource/english/our_work/social_environmental/id/asia/south/india/c8h0vm00009ulddw-att/c8h0vm0000ahd7tr.pdf

36 Ms Rhythma Kaul and Commodore Debesh Lahiri, "Sustainable Ship Recycling in India-Legal, Economic and Political Analysis", National Maritime Foundation, January 2024, https://maritimeindia.org/sustainable-ship-recycling-in-india-legal-economic-and-political-analysis/

37 Shipbreaking Code (Revised) 2013, Government of India, https://shipmin.gov.in/sites/default/files/1157392371CBCODErevised201310022017_0.pdf

38 "Green Ship Recycling Facility", Arya Steel Handbook

39 Ingvild Jenssen, Nicola Mulinaris, Sara Costa, Benedetta Mantoan, Pilar Gianni Rodríguez, "Impact Report 2020-21", NGO Ship Breaking Platform Rue de la Linière 11, B - 1060 Brussels, https://shipbreakingplatform.org/wp-content/uploads/2022/11/NGO-SBP-Annual-Report-2020_2021.pdf

40 Preparatory Survey on the Ship Recycling Yard Improvement Project in India, Final Report (Draft), Japan Marine Science Inc., Padeco Co. Ltd and Japan Development Institute Co. Ltd., Japan International Cooperation Agency, July 2017

41 Environmental Impact Assessment and Environmental Management Plan, July 2016, https://www.jica.go.jp/Resource/english/our_work/social_environmental/id/asia/south/india/c8h0vm00009ulddw-att/c8h0vm0000ahd7tr.pdf

42 *Ibid*

43 *Ibid*

44 Gujarat has full potential to become a green ship recycling hub: Chief Minister, CMO Gujarat, 12 September 2022, https://cmogujarat.gov.in/en/latest-news/gujarat-has-full-potential-to-become-a-green-ship-recycling-hub-chief-minister/

45 Maritime Amrit Kaal Vision 2047, October 2023, Pg. 429 - 433

46 Maritime India Vision 2030, Ministry of Ports, Shipping and Waterways (MoPSW), Government of India, February 2021, Pg. 163-165, https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Air%20pollution/Maritime%20India%20vision%202030.pdf

47 Geetanjoy Sahu, "Working, Living, Occupational Health and Safety Conditions of Workers in Ship Breaking Yards in Alang-Sosiya, Gujarat, India", Tata Institute of Social Sciences (TISS), Mumbai, 2019, https://www.shipbreakingplatform.org/wp-content/uploads/2019/12/Policy-Brief-TISS-Working-Conditions-ASSBY-2019.pdf

48 *Ibid*

49 "Breaking Out: Anchoring Circular Innovation for Ship Recycling", NGO Shipbreaking Platform, 20 September 2022, https://shipbreakingplatform.org/wp-content/uploads/2022/10/Breaking-Out-Magazine.pdf

50 *Ibid*

51 *Ibid*

52 Anand M Hiremath et al, "Significant steps in ship recycling vis-a-vis wastes generated in a cluster of yards in Alang: a case study", *Journal of Cleaner Production*, Volume 87, January 2015, https://www.sciencedirect.com/science/article/abs/pii/S0959652614009615

India's Clean Energy Transition for Shipping

Towards Zero-Emission Shipping for India — The Case for Ammonia versus Hydrogen as the Fuel of Choice

Ms Ayushi Srivastava

As the maritime sector charts its course into the future, it finds itself at a critical juncture, confronting the challenges of decarbonisation amidst economic and geopolitical uncertainties. Greenhouse gas emissions from the shipping industry, constituting 3% of the global total, have surged by 20% in the past decade and, in the absence of decisive action by all stakeholders, threaten to soar to 130% of 2008 levels by 2050.[1] Adding to the complexity is an ageing global fleet, one wherein the average ship's age, as of early 2023, is over 22 years, presenting a dilemma where many vessels are either too old for retrofitting or too new to be scrapped.[2]

The urgency to reduce emissions is palpable, yet the sector grapples with substantial uncertainty in terms of identifying optimal transition strategies. While alternative fuels hold promise, their current utilisation remains in a nascent stage, with a staggering 98.8% of ships still being reliant upon fossil fuels. Encouragingly, however, a notable 21% of vessels on order are slated to operate on cleaner alternatives such as liquefied natural gas, methanol, and hybrid technologies.

Adding another layer of complexity is the question of accountability in this transition. While major flag States, such as Liberia, Panama, and the Marshall Islands, which taken in aggregate, are responsible for a third of shipping's carbon emissions, are indeed poised to enforce new green standards, the economic burden of investing in alternative fuels, bunkering infrastructure, and greener vessels largely falls upon ship owners, ports, and the energy sector as a whole. Navigating this intricate web of economic, regulatory, and environmental imperatives constitutes the industry's next significant trial.[3]

At COP 21 in Paris, on 12 December 2015, the "United Nations Framework Convention on Climate Change" (UNFCCC) adopted the "Paris Agreement", which aims to achieve global climate-neutrality by the middle of the current century.[4] For its part, the global shipping industry is aware of its adverse impact on the climate and has vowed to achieve net-zero CO_2 emissions by 2050.[5] The "International Maritime Organisation" (IMO), too, is focusing on controlling GHG emissions, and its "Marine Environment Protection "Committee (MEPC), has taken a number of remedial measures in this regard. On 13 April 2018, for instance, the 72nd meeting of the MEPC (MEPC-72) adopted the "Initial IMO Strategy on Reduction of GHG emissions from Ships" vide 'Resolution MEPC.304(72)'.[6]

The principal objectives of this 'Initial Strategy' are to enhance IMO's contribution in addressing GHG emissions and identifying actions and measures to reduce the GHG emissions from international shipping by at least 50 per cent by 2050, when compared to 2008. The strategy envisages a decline in carbon intensity through the phased implementation of the "Energy Efficiency Design Index "(EEDI) for new ships and sets a target of reducing CO_2 emissions per transport work, by at least 40 per cent by 2030, and 70 per cent by 2050, compared to 2008.[7]

In July of 2023, IMO member States unanimously endorsed the "2023 IMO Strategy for the Reduction of Greenhouse Gas (GHG) Emissions from Ships", which incorporates even more ambitious targets to address the detrimental impact of emissions.[8] This updated IMO GHG Strategy, adopted in the 80th session of the MEPC (MEPC 80), features a strengthened shared vision to achieve near-zero GHG emissions from international shipping by the vicinity of 2050. It also emphasises a firm commitment to promoting the adoption of alternative 'zero- and near-zero GHG-emitting fuels by the year 2030. Additionally, the strategy establishes key interim milestones, with a baseline reduction target of at least 20%, while striving for 30%; and with a base reduction goal of at least 70%, striving for 80%, by 2040. This marks a significant advancement in global efforts to mitigate the environmental impact of maritime transportation.[9]

Heavy Fuel Oil (HFO) is, even today, the predominant fuel used in ships undertaking long distance voyages. However, it has a high sulphur content and, hence, results in high levels of environmental pollution. "Exhaust Gas Cleaning Systems" (EGCS), commonly referred-to as "scrubbers", are being retrofitted in the machinery of merchant ships, with the aim of reducing sulphur emissions from 3.5% to 0.5%. However, this measure alone is considered insufficient to achieve IMO targets, at least not by its 2050 deadline. Consequently, alternative fuels need to be considered in order to decarbonise shipping.

Shipping is a complex and capital-intensive industry. A 2020 study undertaken by the "University Maritime Advisory Services" (UMAS) and the "Energy Transitions Commission" found that to achieve the IMO's carbon reduction ambition by 2050, funding support of the order of US$ 1 to 1.9 trillion would be needed.[10] Moreover, at least at this point in time, there is no readily available and affordable replacement for conventional fossil fuels. Thus, the decarbonisation of shipping is unlikely in the near-term.

The transition of the shipping industry away from fossil fuels has certainly begun but there is much that must be done before merchant ships can be propelled by zero-carbon fuels. This sobering realisation notwithstanding, there are a variety of non-fossil fuels that have been tentatively identified as having the potential to reduce GHGs emission. Amongst these, hydrogen (H_2) and ammonia (NH_3) are notable. Both consist of carbon-free and sulphur-free molecules; are versatile; and can power applications using fuel cells or internal combustion engines (ICEs).

Comparative Analysis of H_2 and NH_3 Properties

Both hydrogen and ammonia, whether produced from renewable energy or fossil fuel associated with carbon capture technology, can become carbon-neutral fuels. However, the combustion of ammonia and hydrogen can generate nitrogen oxides (NO_x), which have a "Global Warming Potential" (GWP)[11] 273 times that of CO_2. GWP measures how much energy one tonne of a gas absorbs over a given period, relative to one tonne of CO_2 emission. The period generally used for GWPs is 100 years. So, NO_x emitted today would remain in the atmosphere for more than a century.[12] Thus, H_2 and NH_3 might well be carbon-free, but they will require additional technology capable of capturing or significantly reducing NO_x emissions.

Hydrogen has an impressive energy content per unit mass, with a value of 120.2 MJ/kg[13], which compares very favourably with HFO (40.2 MJ/kg) and ammonia (a poor 18.6 MJ/kg).[14] Clearly, hydrogen can increase the effective efficiency of an engine and reduce specific fuel consumption[15] far better than other fuels. However, motorised ships are seagoing vehicles that must, until replenished from an external source, carry the fuel that they consume. Therefore, the amount of fuel that can be carried for a given delivery of energy is another important factor. This is indicated by the "volumetric energy density" (the amount of energy that can be contained within a given volume) of a given fuel.

Here, unlike the case with energy content per unit mass, hydrogen fares the poorest amongst the fuels under consideration, namely, HFO, ammonia, and hydrogen. While HFO has a volumetric energy density that varies from 39,564 MJ/m^3 to 42,036 MJ/m^3, hydrogen gas (even when compressed to 350 bar of pressure) yields a 'volumetric energy density' of just 5,040 MJ/m^3. Even if it is liquified, the 'volumetric energy density' of hydrogen is 8,500 MJ/m^3 — a mere quarter of that of HFO.[16] Thus, to deliver the same quantum of energy as HFO, hydrogen requires around four times the volume of space than HFO would have needed.

Even in comparison with liquid ammonia, which has a 'volumetric energy density' of 14,100 MJ/m^3,[17] hydrogen would require almost double the space for an equivalent amount of energy. Moreover, since liquid hydrogen requires a temperature of less than minus 253^o C, the requirement of space would increase in order to allow for the necessary layers of insulating material for cryogenic storage[18], as well as other ancillary structural arrangements.

Ammonia, on the other hand, can be brought to liquid form at room temperature (25^o C) when pressurised to 9.9 atm or, if the temperature is lower than minus 33.4^o C, at normal atmospheric pressure (one atm). Being 10.6 to 30.2 times cheaper than hydrogen, it is clearly a more cost-efficient option, particularly since its facilities for its transportation and storage already exist, with over 18 million tonnes of ammonia being traded internationally on an annual basis (as of the year 2020).[19]

It may thus be seen that although hydrogen as a marine fuel is characterised by low Greenhouse Gas (GHG) emissions, its storage and handling are challenging. The development of this form of marine fuel requires more advanced technology, considerable innovation, and significant cost reduction. Moreover, the shipping industry has fairly limited experience in dealing with hydrogen as a marine fuel, when compared with ammonia and HFO. The technology maturity[20] of both hydrogen and ammonia need time and the infusion of considerable capital if either is to achieve the end goal of zero-carbon emissions.[21] A brief comparison of maritime fuel characteristics can be found in Table 1,[22] which compares HFO, hydrogen, and ammonia on various aspects.

Table 1. Matrix for maritime fuel characteristic

Fuel		Technology maturity	Applicability to shipping	Well-to-tank	Tank-to-wake	Fuel Safety & Storage	Fuel cost
Hydrogen	Combustion	Medium	Medium	Low	Low	Low	High
	Electric (Fuel cell)	Low	High				
Ammonia	Combustion	Medium	High	Low	Low	Medium	Medium
	Electric (Fuel cell)	Low	High				
HFO	Combustion	High	High	High	High	High	Low
	Low		Medium	High			

Source: Collated by the Author

A 2017 study by Lloyd's Register (LR) and the University Maritime Advisory Services (UMAS) suggests that as a shipboard fuel, ammonia is more economically viable than hydrogen as there are lower costs that are associated with its onboard storage.[23] This notwithstanding, there is no gainsaying the fact that the cost of either of these alternative fuels is, at present, much higher than that of HFO. Likewise, while both hydrogen and ammonia have much lower values of GHG emission when compared to that of HFO, the impact of their respective production processes is likely to erode this advantage. There are four types of hydrogen and ammonia in terms of emissions released during production:[24]

- 'Brown', produced from the processing of coal.

- ‘Grey’, produced from natural gas or by processing of fossil fuels other than coal.
- ‘Blue’, produced from processing of fossil fuels but with carbon-capture technologies.
- ‘Green’, produced from renewable energy sources such as wind, solar, geothermal, water, etc.

Currently, ‘grey’ production is dominant, although a definitive shift to ‘blue’ or ‘green’ hydrogen and ammonia is clearly needed. In the case of hydrogen, this could be achieved by electrolysis, high-temperature water-splitting, or by photobiological water-splitting, or by photoelectrochemical water-splitting. However, none of these methods are as yet capable of large-scale hydrogen production.[25] The situation with respect to ammonia is far more encouraging, given that its production through alkaline electrolysis and air separation powered by hydropower (the Haber-Bosch process), is an industrial method that has been around for the past 100 years — since 1920 at least.[26]

There are several research and development projects that are focussed upon using hydrogen and ammonia as marine fuels for sustainable shipping. These include, *inter alia*, “*The Green Ammonia Consortium*”, in Japan (active since 2019),[27] and the “*Zero Emission Energy Distribution at Sea*” (ZEEDS) project (ongoing since 2019 in Northern Europe).[28] The “*Golden Gate Zero Emission Marine Hydrogen Fuel Cell Vessel”*, initiated by Zero Emission Industries, incorporated the launch of a catamaran fuelled by a proton-exchange membrane fuel cell (PEMFC) in 2021.[29] Likewise, for liquid hydrogen, there are Norway’s “*PILOT-E*” project[30] and Australia and Japan’s “Hydrogen Energy Supply Chain Project”.[31] Several commercial industries, too, are working on clean energy — MAN Energy Solutions, for instance, which has announced that its first ammonia unit could soon be in operation.[32] Likewise, M/s Alfa Laval, a marine fuel system developer, has announced its move to the next generation of fuel gas supply system to replace LPG with ammonia.[33]

As would be evident, the world is still in a transition phase, despite several projects throwing up very encouraging results, especially for vessels of limited size. However, large merchant vessels designed for global cargo movement still have a long way to go before they can reach the goal of zero-carbon emission. According to a report by the "International Chamber of Shipping" (ICC), significantly higher levels of investment and research are required for ongoing projects to reach technical maturity. The report identifies 265 projects that address key technical and systemic challenges to accelerate zero-carbon emissions and opines that to reach even a pre-commercial deployment stage, funding of around US$ five billion would be required.[34]

India and its Transition

As highlighted in the recently released "Climate Change Performance Index 2023"[35] report, India has secured the 8th position, marking a remarkable jump of 2 positions from the previous edition, and now holds the highest rank among the G20 nations in transitioning to a greener future.[36] India has also presented its "Nationally Determined Contributions" (NDC) to the UNFCCC through an initiative known as LiFE, which stands for "Lifestyle for Environment." LiFE is a widespread movement that advocates the thoughtful and purposeful utilisation of resources instead of thoughtless and harmful consumption practices. This commitment entails eight overarching goals, including three specific quantitative targets for the year 2030,[37] namely:

1. Increasing the capacity for non-fossil power generation to 50%.
2. Reducing the emissions intensity of GDP by 45% compared to 2005 levels.
3. Establishing a cumulative additional carbon sink of 2.5-3 billion tonnes of CO_2 equivalent through the expansion of forest and tree cover.

However, if we look into the maritime sector of India as of 2019, the Inland Waterways Transport (IWT) sector was responsible for approximately 277,000 tonnes of CO_2 (t CO_2) emissions. During the same year, India had a fleet of approximately 970 coastal shipping vessels, resulting in the consumption of 1.6 million tonnes of fuel oil and the emission of 5.1 million tonnes of CO_2 (Mt CO_2).[38] Government policies anticipate a nearly threefold increase in annual cargo and passenger movement on inland waterways and a 1.2-fold increase in cargo movement via coastal shipping from 2019 to 2030. It is clear that the growth in fuel consumption and emissions will more than offset the benefits of increased trade or human connectivity, making it imperative to implement appropriate measures to mitigate these adverse consequences.[39]

The government has put into action several initiatives, including the "SAGARMALA" programme,[40] the National Waterways Act,[41] and the Inland Vessels Bill,[42] with the aim of advancing the waterways sector and promoting a shift in transportation modes. However, these policies have a constrained emphasis on transitioning to cleaner fuels. On the other hand, "Maritime India Vision 2023" (MIV 2030) introduces measures to ensure that all ports and maritime bodies adhere to global benchmarks for health, safety, security, and environmental standards, thus addressing broader concerns within the sector.[43] Additionally, under the ambit of the "Maritime *Amrit Kaal* Vision 2047",[44] a concerted effort is being made to decarbonise the maritime industry. This vision outlines specific targets, indicated in Table 2 as Target (2030) and Target (2047), to gauge progress against the 2021[45] status of the shipping sector.

Table 2. Targeted Benchmarks for Decarbonising India's Shipping Sector by 2030 and 2047

Plan	Status (as of 2021)	Target (2030)	Target (2047)
Carbon neutral ports	-	1	14
Developing hydrogen/ ammonia hubs at major ports	-	3	14
Develop circular ports	-	-	14
LNG Bunkering in major ports	1	4	8
Port equipment electrification (%)	-	50	>90
Area under green belt (%)	<10	20	33
Share of renewable energy at ports (%)	<10	>60	>90
GHG emission reduction in domestic/ short sea shipping ferries, port vessels (tugs/craft/ dredgers) & OSVs/PSVs	-	30	70
GHG emission reduction in all coastal/ EXIM vessels	-	10	50

Source: Maritime Amrit Kaal Vision 2047

India's Ministry of Ports, Shipping & Waterways has launched a "National Centre of Excellence for Green Port and Shipping" (NCoEGPS), whose mission is to develop a regulatory framework and technology roadmap for Green Shipping, promoting carbon neutrality and a circular economy in India's maritime sector. India also aims to boost the share of renewable energy in major ports to 60% from the current value of less than 10%, primarily through solar and wind power.[46] In line with India's vision to become a global leader in green shipbuilding by 2030, the Ministry also introduced the "Green Tug Transition Programme" (GTTP). This programme, launched during the inauguration of the NCoEGPS in Gurugram, Haryana, begins with the introduction of "Green Hybrid Tugs" equipped with advanced green hybrid propulsion systems. The GTTP will gradually integrate alternative fuels such as methanol, ammonia, and hydrogen. Targets have been set for deploying these "green" tugs in major ports by 2025, with a goal of converting at least 50% of the entire tug fleet into "green" tugs by 2030. This will play a significant role in reducing emissions and advancing India's sustainable development efforts.[47]

India also recently came up with a major policy enabler by the government for the production of green hydrogen/ green ammonia, using renewable sources of energy. The implementation of this policy is expected to provide clean fuel to the common people of the country, while reducing dependence on fossil fuel and also reduce crude oil imports. Another objective is to have India emerge as an export hub for green hydrogen and green ammonia.[48] While these are steps in the right direction, further research and innovation on future marine fuels is needed to ensure a smooth transition. Fortunately, India's engineering capacity for large-scale renewable hydrogen and ammonia projects is not likely to be a bottleneck.[49]

To unlock India's potential in the field of renewable hydrogen and ammonia, the Cabinet has recently introduced the "National Green Hydrogen Mission" (NGHM), with substantial ($2.4 billion) funding support.[50] The "India Hydrogen Alliance" (IH2A), an industry-driven coalition, is actively engaged in the conversion of the NGHM into large-scale commercial projects. An essential element of this initiative involves establishing "Hydrogen Valleys", where production and consumption centres are co-located, thereby adopting a comprehensive value-chain approach, and fostering public-private partnerships, along the lines of similar hubs currently being developed in Europe. This approach encompasses not only hydrogen production and utilisation, but also encompasses the vital aspects of storage and infrastructure of hydrogen and its derivatives. This comprehensive strategy is critical to ensuring that production and utilisation centres are interconnected, preventing investments from turning into stranded assets.[51]

It is crucial for India to consider the establishment of "Green Shipping Corridors", aligning with the "Clydebank Declaration", which aims to support the creation of at least six green corridors by the middle of this decade, with aspirations for additional ones by 2030.[52] Although India is not a signatory to this declaration,[53] embracing green shipping corridors can pave the way for decarbonisation by establishing a green marine fuel value chain and accelerating the transition from 'brown' to 'green' practices.

However, the "Climate Action Tracker", an international scientific initiative monitoring global government efforts to combat climate change, has assessed India's net-zero goals as "inadequate".[54] According to its assessment, India's "Long-Term Low-Carbon Development Strategy", while addressing specific sectors such as power, industry, transport, buildings, and urban development, lacks a clear direction for achieving net zero emissions beyond the existing initiatives. The strategy fails to present emissions reduction pathways or demonstrate how current policies will lead to the necessary emissions reductions by 2070. Additionally, it lacks transparency regarding the use of technologies such as CCUS (carbon capture, utilisation, and storage)[55] for meeting the net-zero target. India's net zero objective falls short in terms of its comprehensiveness, target framework, and transparency.[56]

Thus, it is necessary to understand the fuel pathway for the shipping sector for a proper transition, and for a balance to be struck between policies and their implementation. Indian shipping industries, too, have to get more actively involved in innovations and could help in achieving the country's net-zero target by specifying the scope of emissions, quantifying mitigation measures and pathways, and establishing a review process for the target.[57]

Recommendations

- Indian policymakers must commit themselves to establishing green shipping corridors to accelerate the development of zero-emission fuels, low-carbon enabling infrastructure, and effective legislation and regulation. These corridors would serve as testbeds for alternative fuel infrastructure and operations, promoting the adoption of low-carbon fuels, encouraging the development of sustainable infrastructure, and facilitating the transition to eco-friendly practices along key maritime routes.
- India should collaborate with leading global green-transition countries such as the US, the UK, Denmark, and Norway, to access best practices, technology, and resources for developing green shipping corridors and promoting sustainable maritime practices, aligning with international initiatives such as the Clydebank Declaration and the Zero Emission Shipping Mission.[58]
- The government needs to leverage digital innovations such as GHG emission calculators, digital twinning, and collaborative platforms, to raise energy efficiency in the maritime sector.
- Leverage the "LeadIT 2.0 Initiative" announced at COP28. The ITP represents a pivotal partnership between India and Sweden, targeting expedited and more ambitious transitions within the industry sector. Facilitated by LeadIT, the ITP would facilitate collaboration between governments, industries, technology providers, researchers, and think tanks of both nations, offering customised bilateral and multilateral technical and financial assistance to support India's transition priorities.[59]
- Increase funding for research and development (R&D) initiatives focused on advancing technologies for green shipping, including hydrogen fuel cells, ammonia propulsion systems, and carbon capture and storage (CCS) technologies. Establish collaborative research partnerships between industry, academia, and government agencies to drive innovation in sustainable maritime solutions.

Conclusion

While maritime transport is undeniably a linchpin of global trade and supply chains, the sector faces formidable challenges in terms of reducing GHG emissions. Yet, a transition away from conventional marine fossil fuels is crucial, especially given the fact that alternative fuels like hydrogen (H_2) and ammonia (NH_3) offer promising paths toward decarbonisation. However, the challenges should not be underestimated, as transitioning to these alternative fuels is a complex and costly endeavour, requiring significant technology innovation and capital investment.

Hydrogen boasts a high energy content but suffers from low volumetric energy density, necessitating larger storage space. Ammonia presents itself as a more cost-efficient option due to its existing infrastructure and lower storage costs. However, both hydrogen and ammonia face similar challenges related to NOx emissions, the addressal of which requires significant additional investments of time, money, and effort, in technology. Further, the production of green hydrogen and ammonia using renewable energy sources is essential to minimise their carbon footprint. Currently, grey production methods predominate, underscoring the need for a shift to 'blue' or 'green' production techniques. Numerous research and development projects are underway to harness hydrogen and ammonia as marine fuels, with promising results for smaller vessels. However, achieving zero-carbon emissions for large merchant vessels involved in global cargo transportation remains a formidable challenge.

Given the ambitious targets set by multiple stakeholders, including those within India, concerted efforts by policymakers, the shipping industry, and the research community, are imperative. Scaling up investment in research, development, and innovation, along with government subsidies for alternative fuel infrastructure, will be crucial to navigate these challenges and steer the maritime sector toward a sustainable, low-carbon future.

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ENDNOTES

1 The choice of 2008 as the baseline year for measuring and reducing greenhouse gas emissions from international shipping by the International Maritime Organization (IMO) and the United Nations Conference on Trade and Development (UNCTAD) was likely influenced by several factors. Firstly, 2008 represented a significant year for climate action, with growing global momentum to address emissions across various sectors. Additionally, the 2008 global financial crisis may possibly have provided a representative snapshot of shipping activity and emissions before the impacts of the economic downturn. By aligning on a common 2008 baseline, the IMO, UNCTAD, and the broader international community could more effectively track progress and coordinate their emissions reduction efforts in the maritime industry over time.Top of Form

2 "Review of Maritime Transport 2023", United Nations Conference on Trade and Development (UNCTAD), 27 September 2023 https://unctad.org/system/files/official-document/rmt2023_en.pdf

3 *Ibid*

4 "The Paris Agreement", United Nations Framework Convention on Climate Change (UNFCCC) https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

5 Dr Stefan Ulreich, *Fuelling the Fourth Propulsion Revolution- an Opportunity for All* (London: International Chamber of Shipping, 2022), 6 https://www.ics-shipping.org/wp-content/uploads/2022/05/Fuelling-the-Fourth-Propulsion-Revolution_Full-Report.pdf

6 "Initial IMO Strategy on reduction of GHG emissions from ships", International Maritime Organisation (IMO), Annex 11, Resolution MEPC.304(72), 13 April 2018 https://

wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Resolution%20 MEPC.304(72)_E.pdf

7 *Ibid*

8 "Revised GHG reduction strategy for global shipping adopted", Press briefing, International Maritime Organisation (IMO), 07 July 2023 https://www.imo.org/en/MediaCentre/PressBriefings/pages/Revised-GHG-reduction-strategy-for-global-shipping-adopted-.aspx

9 "2023 IMO Strategy on reduction of GHG Emissions from ships", Marine Environment, International Maritime Organisation (IMO) https://www.imo.org/en/OurWork/Environment/Pages/2023-IMO-Strategy-on-Reduction-of-GHG-Emissions-from-Ships.aspx

10 Raucci Carlo, Bonello Jean Marc, Suarez de la Fuente Santiago, Tristan Smith, Kasper Søgaard. "Aggregate investment for the decarbonisation of the shipping industry" (PowerPoint presentation, *University Maritime Advisory Services* (UMAS), January 2020) https://www.globalmaritimeforum.org/content/2020/01/Aggregate-investment-for-the-decarbonisation-of-the-shipping-industry.pdf

11 GWP is a metric used to measure and compare the potential climate impact of different greenhouse gases. It is defined as the cumulative radiative forcing, both direct and indirect effects, over a specified time horizon resulting from the emission of a unit mass of a given greenhouse gas, relative to a reference gas. In other words, it is an index that measures how much energy the emissions of one tonne of a gas will absorb over a given period of time, relative to the emissions of one tonne of CO2. Gases with a higher GWP value absorb more energy, per unit mass than gases with a lower GWP, and thus contribute more to warming the Earth

12 "Understanding Global Warming Potentials, Greenhouse Gas Emissions", United States Environmental Protection Agency (EPA) https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

13 Hydrogen has the highest energy density per unit of mass, providing approximately 120 MJ/kg. This high gravimetric energy density makes hydrogen an efficient and lightweight energy carrier. Energy density refers to the amount of energy stored in a given system or region of space per unit volume, which can be measured in energy per unit volume. In the context of fuels, energy density can be measured in gravimetric energy density (energy per unit of mass) and volumetric energy density (energy per unit of volume)

14 Kyunghwa Kim, Gilltae Roh, Wook Kim, and Kangwoo Chun, "A Preliminary Study on an Alternative Ship Propulsion System Fuelled by Ammonia: Environmental and Economic

Assessments", *Journal of Marine Science and Engineering* 8, No 3 (7 March 2020): 183 https://doi.org/10.3390/jmse8030183

15 Specific fuel consumption (SFC) is a measure of the fuel efficiency of an engine, defined as the amount of fuel consumed per unit of power output. It is typically expressed in grams per kilowatt-hour (g/kWh) or pounds per horsepower-hour (lb/hp-h). Compared to traditional marine diesel engines, hydrogen combustion engines can achieve higher efficiencies, with SFC values in the range of 0.2-0.4 kg/kWh. This represents a significant improvement over diesel engines, which typically have SFC between 155-225 g/kWh under optimal conditions

16 *Ibid*

17 *Ibid*

18 Cryogenic storage is essential for liquid hydrogen on ships. Key design considerations include maintaining the critical -253°C temperature, slight overpressure, effective thermal insulation, and safety features like pressure relief systems. Spherical tanks are preferred to minimize heat transfer and interaction with the environment. The tank connection space (TCS) provides a gas-tight enclosure for components, facilitates safety integration, and supports efficient operation

19 Kyunghwa Kim, Gilltae Roh, Wook Kim, and Kangwoo Chun, "A Preliminary Study on an Alternative Ship Propulsion System Fuelled by Ammonia: Environmental and Economic Assessments", *Journal of Marine Science and Engineering* 8, No 3 (7 March 2020): 183 https://doi.org/10.3390/jmse8030183

20 Technology maturity refers to the state of development or evolution of a particular technology. It describes how advanced and refined a technology is, and whether it has reached a stable and reliable state

21 Tristan Smith et al. *A strategy for the Transition to Zero-Emission Shipping.* University Maritime Advisory Services (UMAS) on behalf of the Getting to Zero Coalition, October 2021, https://www.globalmaritimeforum.org/content/2021/10/A-Strategy-for-the-Transition-to-Zero-Emission-Shipping.pdf

22 "Decarbonising Shipping: All hands on deck 2.0", Shell Global in collaboration with Deloitte, 2023 All Hands on Deck 2.0

See Also: Joseph Taylor, Dr Jean-Marc Bonello, Dr Domagoj Baresic and Dr Tristan Smith, *Future Maritime Fuels in the USA – the options and their potential pathways,* (London: University Maritime Advisory Services (UMAS), January 2022), 59, https://oceanconservancy.org/wp-content/uploads/2022/04/oc_fuels_final_report_20220117.pdf

See Also: "Ammonfuel – an industrial view of ammonia as a marine fuel", Alfa Laval, Hafnia, Haldor Topsoe, Vestas, and Siemens Gamesa, 2020 https://hafniabw.com/news/ammonfuel-an-industrial-view-of-ammonia-as-a-marine-fuel/

See Also: "Hydrogen as Marine Fuel", American Bureau of Shipping (ABS), June 2021 https://ww2.eagle.org/content/dam/eagle/publications/whitepapers/hydrogen-as-marine-fuel-whitepaper-21111.pdf

See Also: Charlie McKinlay, Stephen R Turnock, and Dominic Antony Hudson, "A comparison of hydrogen and ammonia for future long distance shipping fuels", (Paper presented at LNG/LPG and Alternative Fuel Ships, London, January 2020), 13 https://www.researchgate.net/publication/339106527_A_Comparison_of_hydrogen_and_ammonia_for_future_long_distance_shipping_fuels

23 "Zero-Emission Vessels 2030—How Do We Get There", Lloyd's Register (LR) & University Maritime Advisory Services (UMAS), 2017. https://maritime.lr.org/zero-emission-vessels-report

24 Joseph Taylor, Dr Jean-Marc Bonello, Dr Domagoj Baresic and Dr Tristan Smith, *Future Maritime Fuels in the USA – the options and their potential pathways,* (London: University Maritime Advisory Services (UMAS), January 2022), 59. https://oceanconservancy.org/wp-content/uploads/2022/04/oc_fuels_final_report_20220117.pdf

25 "Hydrogen as Marine Fuel", American Bureau of Shipping (ABS), June 2021 https://ww2.eagle.org/content/dam/eagle/publications/whitepapers/hydrogen-as-marine-fuel-whitepaper-21111.pdf

26 "Ammonfuel – an industrial view of ammonia as a marine fuel", Alfa Laval, Hafnia, Haldor Topsoe, Vestas, and Siemens Gamesa, 2020 https://hafniabw.com/news/ammonfuel-an-industrial-view-of-ammonia-as-a-marine-fuel/

27 Bunro Shiozawa, "CO2 Free Ammonia as CO2 Free Fuel and Hydrogen Carrier" (PowerPoint Presentation, Cross-ministerial Strategic Innovation Promotion Program (SIP), Tokyo, Japan, 2019)

28 Zero Emission Energy Distribution at Sea (ZEEDS) https://zeedsinitiative.com/

29 Zero Emission Industries https://www.zeroei.com/

30 PILOT-E Funds to develop a supply chain for liquid hydrogen for ships, FuelCellsWorks, 1 May 2021 https://fuelcellsworks.com/news/pilot-e-funds-to-develop-a-supply-chain-for-liquid-hydrogen-for-ships/

31 Hydrogen Energy Supply Chain (HESC) https://www.hydrogenenergysupplychain.com/

32 Nils Lindstrand, "Unlocking ammonia's potential for shipping", MAN Energy Solutions https://www.man-es.com/discover/two-stroke-ammonia-engine

33 "The Alfa Laval FCM LPG Booster System Excels with the New LPG-Fuelled Engine from MAN Energy Solutions", Alfa Laval, 17 April 2019. Alfa Laval - Press Release

34 "A zero emission blueprint for shipping", International Chamber of shipping and in collaboration with Ricardo, November 2021 https://www.ics-shipping.org/wp-content/uploads/2021/11/A-zero-emission-blueprint-for-shipping.pdf

35 The Climate Change Performance Index (CCPI) 2023 is an annual report that evaluates and compares the climate protection performance of 63 countries and the EU, which collectively account for more than 90% of global greenhouse gas emissions. The index measures countries' efforts in four key categories: Greenhouse Gas Emissions (40% weighting), Renewable Energy (20% weighting), Energy Use (20% weighting), and Climate Policy (20% weighting).

Achieving a good ranking in the CCPI has significant implications. It reflects a country's strong commitment to rapid improvements in energy efficiency, renewable energy, and ambitious climate policy.A high ranking showcases a country's alignment with the well-below 2°C pathway set out in the Paris Agreement, signalling its dedication to meeting climate targets. It also serves as a powerful incentive for countries to further advance their climate action efforts. Overall, a good CCPI ranking is a recognition of a country's progress in climate change mitigation and a catalyst for continued environmental progress.

36 "Climate Change Performance Index", Ministry of Environment, Forest and Climate Change, Press Release, 19 December 2022 https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1884764#:~:text=The%20Climate%20Change%20Performance%20Index,i.e%201%2D3%20are%20vacant

37 "India's Updated First Nationally Determined Contribution Under Paris Agreement (2021-2030)", Government of India, August 2022 https://unfccc.int/sites/default/files/NDC/202208/India%20Updated%20First%20Nationally%20Determined%20Contrib.pdf

38 Nilanshu Ghosh, Abhinav Soman, Harsimran Kaur, and Himani Jain, *Decarbonising Shipping Vessels in Indian Waterways through Clean Fuel*, (CEEW The Council and Shell Foundation, March 2023) 18.

39 *Ibid*

40 "Sagarmala programme", Press Information Bureau, Ministry of Shipping, Government of India, 12 March 2020 https://pib.gov.in/newsite/PrintRelease.aspx?relid=200158

41 "The National Waterways Act 2016", Law and Environment Assistance Platform (LEAP), UN environment programme https://leap.unep.org/countries/in/national-legislation/national-waterways-act-2016

42 "The Inland Vessels Act 2021", The Gazette of India, Ministry of Law and Justice, August 2021 https://iwai.nic.in/sites/default/files/IV%20Act%202021%20Gazette_0.pdf

43 "Maritime India Vision 2030", Ministry of Ports, Shipping and Waterways (MoPSW), Government of India, 2021 https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Air%20pollution/Maritime%20India%20vision%202030.pdf

44 "Maritime Amrit Kaal Vision 2047", Ministry of Ports, Shipping and Waterways, Government of India, 2023 Maritime Amrit Kaal Vision 2047

45 The targets set in the Maritime Amrit Kaal Vision 2047 are compared with the 2021 status to establish a clear baseline and measure the progress over time.

46 "National Centre of Excellence for Green Port & Shipping (NCoEGPS) aimed at providing Green solutions to transform Ports & Shipping: Shri Sonowal", Press Release, Ministry of Ports, Shipping and Waterways, Government of India, 2022 https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1877297

47 "India aims at becoming 'Global Hub for Green Ship' building by 2030 with launch of Green Tug Transition Programme (GTTP): Shri Sarbananda Sonowal", Press Release, Ministry of Ports, Shipping and Waterways, Government of India, 22 March 2023 https://pib.gov.in/PressReleasePage.aspx?PRID=1909599

48 "Ministry of Power notifies Green Hydrogen/ Green Ammonia Policy", Press Release, Ministry of Power, Government of India, 2022 https://pib.gov.in/PressReleasePage.aspx?PRID=1799067

49 Kevin Rouwenhorst, "India: a future ammonia energy giant", Ammonia Energy Association, 13 April 2023 https://www.ammoniaenergy.org/articles/india-a-future-ammonia-energy-giant/

50 "National Green Hydrogen Mission", Press Release, Ministry of New and Renewable Energy, Government of India, January 2023 https://mnre.gov.in/img/documents/uploads/file_f-1673581748609.pdf

51 Kevin Rouwenhorst, "India: a future ammonia energy giant", Ammonia Energy Association, 13 April 2023 https://www.ammoniaenergy.org/articles/india-a-future-ammonia-energy-giant/

52 "COP26: Clydebank Declaration for green shipping corridors", policy paper, Department of Transport, GOV.UK, updated on 13 April 2022 https://www.gov.uk/government/publications/cop-26-clydebank-declaration-for-green-shipping-corridors/cop-26-clydebank-declaration-for-green-shipping-corridors

53 *Ibid*

54 Climate Action Tracker, Climate Analytics and New Climate Institute https://climateactiontracker.org/#:~:text=The%20Climate%20Action%20Tracker%20is,warming%20to%201.5%C2%B0C.%22

55 Carbon capture, utilization, and storage (CCUS) is a process that involves capturing CO2 emissions from industrial operations, transporting it, and then either utilizing it in various industrial processes or permanently storing it deep underground.

56 "Understanding India's Net Zero Policies: A Primer for Journalists", *Earth Journalism Network*, 27 July 2023 https://earthjournalism.net/resources/understanding-indias-net-zero-policies-a-primer-for-jou-rnalists

57 *Ibid*

58 India, as one of the four core mission members in the Zero Emission Shipping Mission of the Mission Innovation to support the decarbonization of the maritime sector and achieve net-zero greenhouse gas emissions by 2050.

59 LeadIT 2.0 launched at COP28: driving inclusive industry transition forward, Leadit Leadership Group for Industry Transition, 12 December 2023 https://www.industrytransition.org/insights/leadit-2-0-launched-at-cop28-driving-inclusive-industry-transition-forward/

Book Review

"The Next Stop: Natural Gas and India's Journey to a Clean Energy Future"

Vikram Singh Mehta, Ed. Noida: Harpercollins Publishers, 2021.
640 Pages, Rs 490 (Hardcover)

Ms Harshita Dey

The world is yearning for a breath of fresh air — a more sustainable and secure energy future. This burning desire is especially evident in India, a nation grappling with its ever-growing energy needs. Vikram Singh Mehta's edited volume, "*The Next Stop: Natural Gas and India's Journey to a Clean Energy Future*," makes a timely entry into this conversation and throws open the hood on India's natural gas sector. The authors collectively propose natural gas as a "bridge fuel", that is, a temporary solution to help India navigate away from "dirty" coal towards a cleaner energy future. The book delves into the nitty-gritty of India's natural gas landscape, leaving practically no stone unturned.

The book is helmed by Vikram Singh Mehta, a well-known veteran in the field of India's energy, who transitioned from the corporate trenches to become a respected analyst. Mehta, formerly the CEO of Shell India, brings his industry expertise to the table as an editor. While international experts lend their voices throughout the book, the section "*India – The Current Setting*" is firmly grounded in the perspectives of domestic specialists, offering a nuanced view of India's unique energy landscape.

The book opens with a stark reality check: India's economy is on a tear, but its continued reliance on fossil fuels, particularly the dirty king coal, is wreaking havoc on the environment. Renewable energy sources are emerging as strong contenders, but they are not yet quite ready to plug the energy gap for the foreseeable future. So, what then, is the plan? The book proposes a strategic pit-stop on the road to clean energy: natural gas, the "cleanest"[1] of the fossil fuels. Mehta and his team advocate for natural gas as a *bridge fuel*, a temporary solution to wean India off coal and steer it towards a cleaner energy future.

The book casts a spotlight on the roadblocks that threaten to derail India's natural gas aspirations. One major obstacle is the scarcity of recoverable reserves of natural gas within the country's sedimentary basins. These reserves often reside in geologically treacherous areas, making extraction a backbreaking and expensive endeavour. Compounding this challenge is the lack of a robust national gas pipeline network. Think of it as a highway system with missing links — it hinders the smooth flow of gas from production sites to hungry consumers. The book further criticises the current policy framework for natural gas, pointing to a labyrinthine pricing structure and complex formulae that leave consumers scratching their heads in bewilderment. To make matters worse, natural gas is currently excluded from the Goods and Services Tax (GST). However, central excise duty, state VAT, and central sales tax, are all levied, leading to inflated costs for end users.

The book takes the reader on a deep dive into the intricate world of natural gas, meticulously dissecting each step in the value chain. From the initial stages of gas production and liquefaction to transportation via specially designed cryogenic ships, the book unpacks the entire natural gas odyssey. It explains how contemporary solutions such as 'Floating Liquefied Natural Gas' (FLNG) units — essentially miniature gas-processing plants on ships — and 'Floating Storage Regasification Units' (FSRUs) — giant, floating gas-storage tanks — are transforming the industry.

Shifting gears, the book delves into the dynamics of the global natural-gas market, highlighting the growing trend of market-based pricing and flexible contracts. It analyses the emergence of Australia as a major natural gas exporter, contrasting the Australian approach with the long-term, oil-indexed contracts favoured by many Asian countries. This comparison also sheds light upon the evolving power dynamics within the global natural-gas market.

Refreshingly, the book prescribes a slew of recommendations and solutions as well. At the broad level, the authors advocate a major shake-up in the natural-gas import landscape so as to capitalise upon these sorts of advancements. For one, they propose restructuring GAIL (Gas Authority of India Limited) to foster competition within the sector, potentially leading to a more efficient and responsive gas market. They strongly recommend a shift towards market-based pricing — a more dynamic approach that reflects real-time market forces. Additionally, they push for more flexible contracts, allowing India to adapt to changing circumstances. The book also emphasises the need for a policy overhaul that prioritises natural gas. This includes streamlining the inclusion of natural gas within the Goods and Services Tax (GST) to reduce end-user costs.

"The Next Stop" champions a multi-pronged approach to propel India's natural gas ambitions. First, it calls for a policy shift that prioritises natural gas and streamlines the current labyrinthine pricing structure. Secondly, it proposes including gas under the GST to ease the burden on consumers and advocates for restructuring GAIL to foster competition within the sector.

Recognising that government intervention alone is insufficient, the book emphasises the need for robust collaboration between central and state governments, the private sector, and even consumers. This echoes the importance of a well-oiled machine — all parts working together to overcome roadblocks such as land-acquisition disputes and disagreements over pipeline routes. While acknowledging the environmental concerns surrounding natural gas, the book does not shy away from its potential to displace "dirtier" options in sectors such as transportation and industry, offering a glimpse into a cleaner future.

"*The Next Stop*" shines brightest in its comprehensive approach and meticulously crafted flow of information. Authored by a team of industry veterans, each chapter delves into a specific aspect of the natural gas value chain or a related policy issue. The book does not avoid complexity, but instead fortifies understanding with detailed charts, graphs, and references. The authors even take a brave dive into the often-opaque world of "*Shipping Liquefied Natural Gas*," a topic that strikes a nerve with natural gas carrier owners due to the current lack of profitability. This commitment to transparency is further bolstered by a later chapter that makes a compelling case for India to take control of its natural-gas destiny. The book proposes domestic ownership of natural gas carriers, essentially exhorting India to *"get behind the wheel"* of its natural gas imports. This bold suggestion foretells a future where India plays a far more proactive role in the global natural gas market.

While *"The Next Stop"* boasts a wealth of information, its sheer volume can be overwhelming. Writing styles vary across chapters, and key points are repeated like well-worn records, leaving first-time readers, especially those unfamiliar with the energy sector, struggling to absorb the information. Although the book acknowledges the rise of new-natural gas producers, a deeper exploration of the geopolitical chess game surrounding India's growing dependence on imported gas would have added another layer of intrigue. Perhaps most striking is the fact that the book's recommendations, published in 2021, remain as relevant today as they were then. And yet, despite the book's compelling arguments, the government has not implemented any of the suggested changes. This highlights the often-glacial pace of policy implementation, even in the face of pressing challenges.

"*The Next Stop*" meticulously dissects India's natural gas sector, but it stops short of delivering a truly impactful punch. While it acknowledges the suffocating grip of air pollution on public health, this critical issue is relegated to the sidelines. A dedicated chapter exploring the potential for natural gas to improve the lives of ordinary Indians would have resonated more deeply amongst readers. Imagine the book quantifying the potential for cleaner air to translate into fewer hospital visits and healthier lungs for millions. It could even propose specific strategies for incorporating natural gas into the energy mix of India's 14 most polluted cities. This granular approach, focusing on the human cost of air pollution in real places, would have driven home the emotional argument for natural gas far more tellingly. By connecting with the plight of everyday people struggling to breathe, the book could have become a much more persuasive advocate for a cleaner energy future approached across the bridge of natural gas.

Despite this expressed desire for more, it must be admitted that "*The Next Stop*" certainly does offer a valuable and meticulously drawn roadmap for India's journey towards a cleaner energy future. While some portions of the book's deep dive into the natural gas sector might leave lay readers scrambling for a life raft, its value as a resource for policymakers and energy professionals is undeniable. While advocating for natural gas as a stepping stone on the path to renewable energy, "*The Next Stop*" offers a clear-eyed view of the hurdles and challenges facing India's quest for just such a future.

21 April 2024

About the Reviewer

Ms Harshita Dey was a Junior Research Associate at the National Maritime Foundation. Her area of Interest was Maritime Geostrategies and varying nuances of Maritime History.

ENDNOTES

1 Natural gas produces 40% less carbon dioxide (CO_2) than coal and 30% less than oil, which makes it the cleanest of the fossil fuels.

Tourism and Sea Port Management

Unlocking the Need for Sustainability in Blue Tourism

Ms Ayushi Srivastava and Commodore Debesh Lahiri (Retd)

Coastal and marine tourism constitutes approximately 50 per cent of all global tourism, equal to US$4.6 trillion or 5.2 per cent of global gross domestic product (GDP).[1] It is a vital component of the economy of small islands and coastal communities.[2] In 2021, the estimated size of the global coastal and maritime tourism market was USD 2.9 trillion, and it is anticipated to grow at a compound annual growth rate (CAGR) of 5.7% from 2022 to 2030.[3] Marine and coastal destinations were not impervious to the repercussions of the COVID-19 pandemic. The complete disruption of the steady influx of tourists via air travel and cruise ships had far-reaching consequences on businesses, governments, and communities. Nevertheless, even though the pandemic underscored the tourism sector's susceptibility to economic, political, and health crises, it also presented an opportunity for fundamental changes within the industry, aiming for a more sustainable future.[4]

The cruise-ship tourism industry is one of the most significant subsectors of marine and coastal tourism. Cruise-ship tourism contributes US$150 billion to the global economy every year and supports 1.2 million jobs, paying US$50 billion in wages.[5] According to the UN World Tourism Organization and Asia-Pacific Tourism Exchange Center, cruise-ship tourism is a 'relatively young phenomenon' that emerged 50 years ago, yet is outperforming general annual tourism growth by around 8 per cent, becoming the fastest-growing type of leisure tourism.[6] The growth of the cruise-ship tourism sector has introduced new socio-economic opportunities, including improved standards of living, increased employment and training options, diversification for local communities, and the socio-cultural benefits that come from interactions between individuals from diverse cultural backgrounds. Nonetheless, the adverse effects of the conventional model of unrestricted tourism sector growth are quite evident.[7]

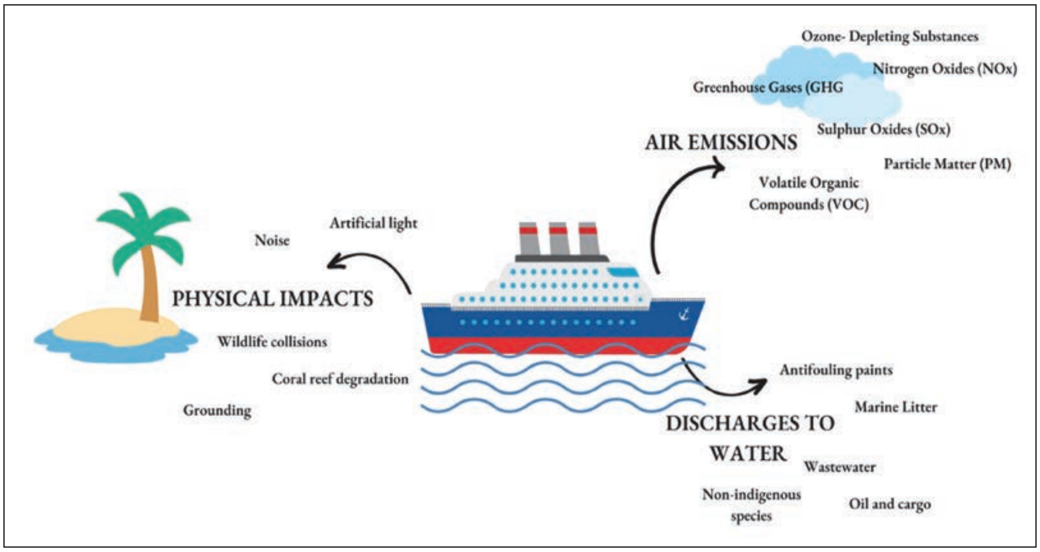
The burgeoning cruise-ship tourism industry is witnessing a notable surge in vessel dimensions and an enhanced array of travel destinations to cater to the rising customer demands. Consequently, the magnificence of these destinations, characterised by their inherent natural beauty, plays a pivotal role in satisfying the escalating demand. It is imperative to acknowledge that the cruise industry is intricately tied to environmental stewardship and regulatory adherence. For instance, research reveals that the cruise-ship tourism sector produces a considerably larger quantity of waste and pollutants compared to any other segment within the maritime industry.[8]

Cruise-ship Tourism and Pollution

Cruise ships make a substantial contribution to environmental pollution, encompassing air pollution, water pollution, solid-waste contamination, chemical pollutants, noise, ballast-water issues, coral-reef degradation, and harm to marine ecosystems. Environmental organisations have likened cruise ships to "floating cities" that have a significant impact on the environment.[9] Research findings indicate that during a seven-day voyage, passengers on an Antarctic cruise can release carbon emissions per traveller equivalent to the annual average for an individual in Europe.[10]

Analysis reveals that a single person aboard a typical cruise-ship generates approximately 421.43 kilograms of CO_2 per day. Conversely, an individual who opts for a high-end hotel stay, utilises carbon-intensive transportation, and engages in higher-carbon activities, emits a significantly lower 81.33 kilograms of CO_2 per day. In comparison, the carbon footprint of an average vacationer on land stands at approximately 51.88 kilograms, which is less than one-eighth of that of the typical cruise-ship passenger.[11] Cruise ships, despite industry efforts to promote environmentally friendly practices, are recognised as significant contributors to carbon emissions, exerting an inequitable influence on the well-being of port communities

Figure 1: Impact of a cruise-ship upon the environment



Source: Collated by the Authors

and destinations. In 2019, cruise vessels sailing from Seattle to Alaska during the six-month cruise season collectively released a substantial 1,120,324 tonnes of CO_2 equivalent — roughly equivalent to 1.1 million tonnes of gas emissions.[12]

According to a June study conducted by the European Federation for Transport and Environment, 63 cruise ships under the ownership of the parent company, Carnival Corporation, emitted 43% more sulphur oxides — a harmful group of air pollutants — in 2022 than all of Europe's 291 million cars combined. This statistic, although alarming, represents a significant reduction compared to a few years ago when Carnival Corporation's ships visiting European ports in 2017 emitted ten times the sulphur oxides produced by all European cars.[13] This decline can be primarily attributed to a 2020 rule established by the International Maritime Organization, which lowered the sulphur content limit of ship fuel from 3.5% to 0.5%.[14] However, despite reducing sulphur emissions per ship, the increasing number of cruise ships and their extended stays in European ports has led to an overall 9% increase in sulphur oxide emissions from cruise ships in 2022 compared to 2017, as reported by Transport & Environment.[15]

The cruise industry transports thousands of individuals worldwide on a single voyage, and these passengers generate substantial quantities of sewage, grey water, oily bilge water, solid waste, and hazardous waste. Regrettably, this waste poses a threat to the delicate marine ecosystem, as even the least harmful substances can harm the surrounding flora and fauna. According to the Bureau of Transportation Statistics, a 3,000-passenger cruise-ship generates the following amount of waste on a typical one-week voyage:

Table 1: Waste discharged by a 3000-passenger cruise-ship on a typical one-week voyage

Type of waste	Estimated amount generated (typical one-week voyage)	Content/type
Sewage (blackwater)	7,94,936.475 litres	Wastewater and solids from toilets
Greywater	37,85,411.8 litres*	Wastewater from sinks, showers, galleys, laundries. Contains detergents, cleaners, oil and grease, metals, pesticides, medical and dental wastes
Hazardous wastes	416.395 litres	Photo chemicals
	18.9271 litres	Drycleaning waste (perchloroethylene and other chlorinated solvents)
	416.395 litres	Used paint
	18.9271 litres	Expired chemicals, including pharmaceuticals
Solid waste	8 tonnes	Plastic, paper, wood, cardboard, food, cans, glass
Oily bilge water	94635.295 litres	Liquid collected in the lowest point in the boat when the boat is in its static floating position
* The interim Alaska report indicates that on average, cruise ships release 757082.357 litres of treated blackwater and greywater per day, with larger cruise ships potentially discharging up to 1324894.1244 litres per day		

Source: Summary of Cruise-ship Waste Streams, Bureau of Transportation Statistics16

Ballast water, crucial for safe shipping operations, maintains balance and stability for ships. However, its improper disposal poses a significant risk to marine ecosystems, introducing new species to foreign waters. For instance, signs of an introduction of an alien species were initially identified by scientists during a widespread outbreak of the Asian phytoplankton algae Odontella (Biddulphia Sinensis) in the North Sea in 1903. However, it wasn't until the 1970s that the scientific community began to scrutinise this issue in-depth. In the late 1980s, Canada and Australia faced significant challenges related to invasive species, prompting them to raise their concerns with the International Maritime Organization's Marine Environment Protection Committee (MEPC).[17] This discharge of contaminated ballast water presents hazards like introducing exotic species, altering ecosystems, and causing species extinctions through predation or competition.[18]

Cruise ships, while insulated internally for noise and vibration, lack exterior insulation, disrupting communication and sonar for sea mammals. Ship noise pollution, which can travel great distances, harms marine species reliant on sound for orientation, communication, and feeding. It has disrupted typical behaviour patterns, hindered feeding, heightened stress levels, and obscured communication. These effects can lead to injuries and fatalities.[19] Wildlife collisions pose risks to marine mammals such as whales and manatees, with even a ship traveling at just 15 knots having a 79% chance of causing lethal collisions.[20] Over the past five years (and since 2021 in particular), the National Oceanic and Atmospheric Administration (NOAA) has identified at least 112 dead whales that washed-up with injuries consistent with ship collisions. However, this alarming statistic does not account for whales that do not wash ashore, leaving the actual number of harmed whales currently unknown.[21]

Ships generally have a detrimental impact on oceans and sea life, with 90 countries reporting severe damage to coral reefs due to anchorage and sewage disposal. A single day of anchor drops can destroy extensive coral reef areas. Addressing these environmental concerns is essential to maintaining comfort and profit while reducing harm to coral reefs.[22]

India and Cruise-ship Tourism

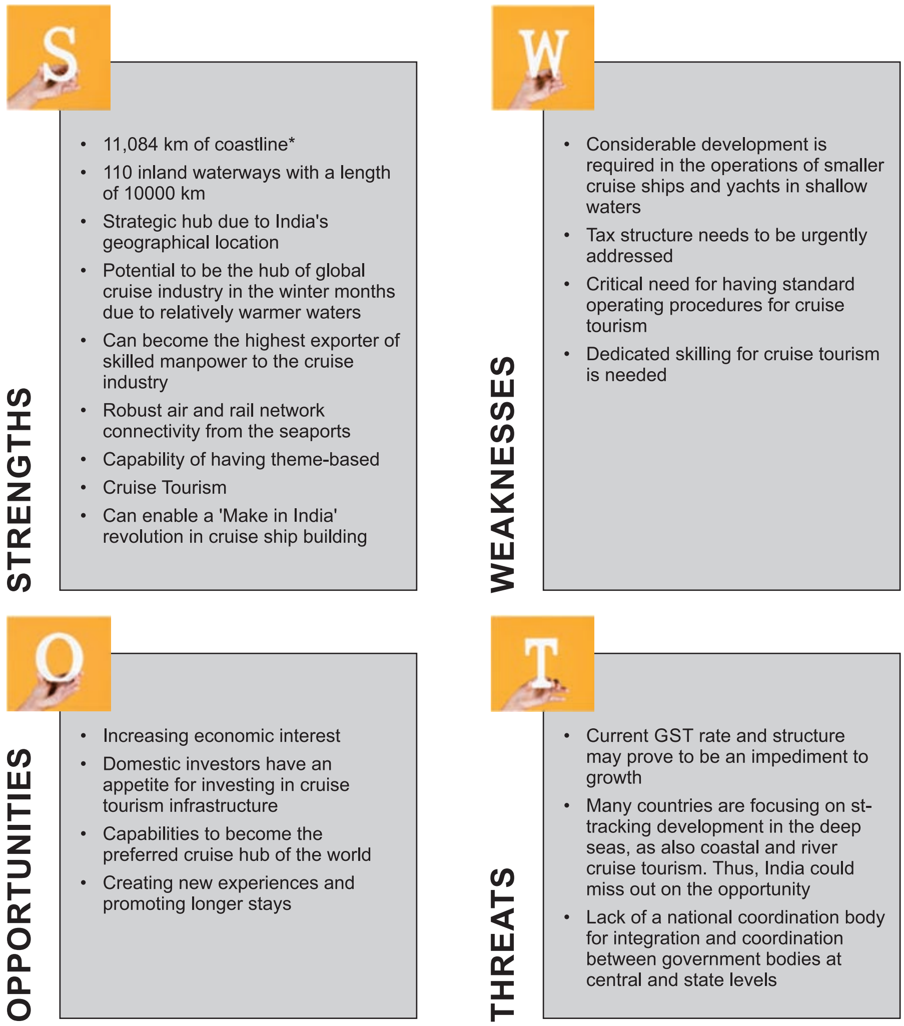
Cruise-ship tourism plays a vital role in India's economic development, attracting substantial foreign capital and significantly contributing to the country's revenue generation. In coastal regions, there is a noticeable convergence of economic, environmental, and demographic pressures, resulting in a complex situation that poses multifaceted challenges to the effective and sustainable management and governance of these coastal zones.[23] India possesses substantial potential in the realm of cruise tourism, particularly in its coastal and river sectors. This potential is underpinned by a variety of factors. To begin with, India boasts an extensive coastline stretching over 11,804 km[24] along both the western and eastern coastal and islandic areas, featuring 12 major ports and over 200 non-major ports. Additionally, the country has an intricate network of navigable waterways spanning over 20,000 km, interconnecting around 400 rivers. Moreover, India's coastal regions, riverbanks, and national waterways are dotted with numerous states, union territories, and over 1300 islands, further enhancing its appeal for cruise tourism.[25]

Indeed, India envisions itself as a "Global Hub for Cruise-ship Tourism".[26] In pursuit of this vision, it is crucial to understand the industry through a SWOT analysis (a SWOT analysis is a strategic planning tool used to assess the Strengths, Weaknesses, Opportunities, and Threats (SWOT) of an organization or industry). It provides valuable insights into internal and external factors that can impact the industry's performance and helps in formulating effective strategies for growth and development.)[27]

India has set itself ambitious goals to grow cruise passenger traffic from its current 0.4 million to 4 million passengers.[30] The economic potential of the cruise tourism industry is expected to increase significantly, going from USD 110 million to a projected USD 5.5 billion in the coming years.[31] To bolster the cruise-ship tourism sector in the country, the Government of India has initiated a number of significant measures, including upgrading infrastructure, rationalising port fees, eliminating ousting charges, prioritising berthing for cruise ships, and offering e-visa facilities.

Cruise-ship tourism has witnessed remarkable year-on-year growth at a rate of 35%.[33] India is actively committed to enhancing cruise-ship tourism within the nation. This commitment is reflected in the Government of India's "Maritime Vision Document 2030",[34] which places strong emphasis on various forms of tourism circuits, including heritage tourism, Ayurveda tourism, coastal tourism, and river-cruise tourism. These circuits include Gujarat Pilgrimage tours, Cultural and Scenic tours along and off the country's western coast, Ayurvedic Wellness tours along and off the country's southern coast, and Heritage tourism along and off the country's eastern coast — all designed to stimulate demand for cruise-ship tourism. Additionally, efforts are underway to create appealing attractions such as lighthouses and islands

Figure 2: SWOT Analysis of Cruise-ship Tourism Industry

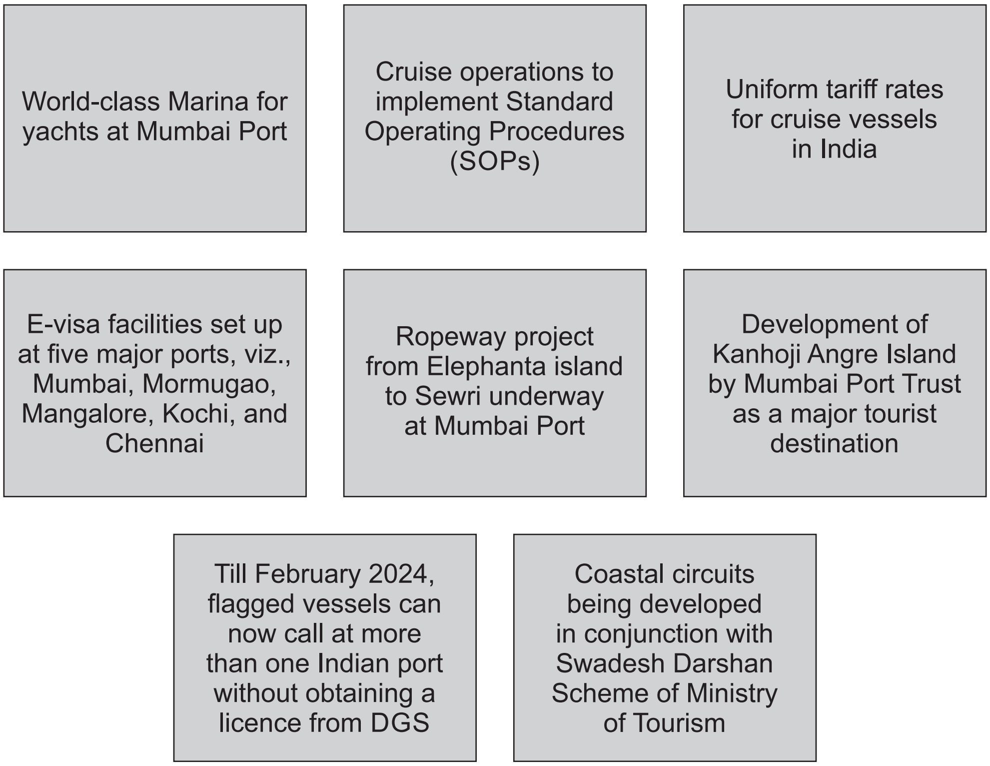


Source: Collected by Authors, Draft National Strategy for Cruise Tourism, and Incredible India International Cruise Conference 2022

along the coast to draw in more tourists. India also recognises the potential of river and inland cruises as valuable components of its cruise-ship tourism offerings.

Significant upgrades and modernization efforts are underway at seven major ports across the country, with the flagship project being the New International

Figure 3: Key Port Initiatives for Cruise-ship Tourism



Source: Sagarmala Post (March) 2020 Edition32

Cruise Terminal in Mumbai, incorporating a financial outlay of approximately Rs 495 crores. The iconic sea cruise terminal at BPX-Indira Dock is scheduled for commissioning by July 2024 and will be capable of handling 200 ships and up to 1 million passengers annually. Similar infrastructure enhancements are being carried out in other ports such as Goa, New Mangalore, Kochi, Chennai, Visakhapatnam, and Kolkata.[35]

Conclusion

Tourism possesses the capacity to impact — directly and indirectly — all 17 of the Sustainable Development Goals (SDGs) goals, especially SDGs 8, 12, and 14. These goals lay focus on fostering inclusive and sustainable economic growth, promoting sustainable consumption and production (SCP), and ensuring the sustainable utilization of oceans and marine resources, respectively. Within the 2030 Agenda, sustainable tourism holds a crucial position. However, actually realising this agenda necessitates the creation of a well-defined implementation framework, and substantial investments in technology, infrastructure, and human resources.[36]

The International Maritime Organization (IMO) defines sustainable development as a type of development that satisfies current needs without jeopardising the capacity of future generations to fulfil their own needs. Additionally, it articulates that this concept encompasses two fundamental elements: first, the concept of 'needs', with a particular emphasis on addressing the critical needs of the world's impoverished populations as a top priority; and secondly, the notion of 'constraints' imposed by the state of technology and social organisation on the environment's capacity to satisfy both present and future needs.[37]

To prevent irresponsible discharge of pollutants and invasive species into the sea, governments and agencies must enforce the guidelines stipulated in the Ballast Water Management Convention of 2004. These guidelines include implementing Ballast Water and Sediments Management Plans, maintaining Ballast Water Record Books, and adhering to ballast water management procedures. Sustainable practices in transportation operations, including minimising non-renewable resource-consumption and promoting reuse and recycling, can further enhance environmental sustainability.[38]

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ENDNOTES

1 Northrop Eliza, "Opportunities for transforming coastal and marine tourism towards sustainability, regeneration and resilience", *High level panel for A Sustainable Ocean Economy*, 2022

2 *Ibid*

3 Coastal and Maritime Tourism Market Size, Share & Trends — Analysis Report", *Grand View Research*, 2022, https://www.grandviewresearch.com/industry-analysis/coastal-maritime-tourism-market-report

4 Balestracci Giulia and Dr Angelo Sciacca, "Towards Sustainable Blue Tourism: Trends, Challenges and Policy Pathways", *Blue Tourism Initiative*, June 2023

5 "Joint statement to support the safe resumption of cruise ship operations following the COVID-19 pandemic", *World Tourism Organisation (UNWTO)* and *International Maritime Organisation (IMO)*, November 2020, https://webunwto.s3.eu-west-1.amazonaws.com/s3fs-public/2020-11/201105-joint-statement-imo-en.pdf

6 "Sustainable Cruise Tourism Development Strategies – Tackling the Challenges in Itinerary Design in South-East Asia", *World Tourism Organization (UNWTO)* and *Asia-Pacific Tourism Exchange Center*, 2016.

7 Northrop Eliza, "Opportunities for transforming coastal and marine tourism towards sustainability, regeneration and resilience", *High level panel for A Sustainable Ocean Economy*, 2022

8 Anderson Kirkland Robert, "Tourism Impact on Environmental Sustainability: A Focus on the Cruise Industry", in Tourism, eds Syed Abdul Rehman Khan, 06 October 2021

9 Okafor Jennifer, "Environmental Impact of Cruise Ships and Cruise Vacations", trvst, 20 September 2023, https://www.trvst.world/environment/environmental-impact-of-cruise-ships/#cmf_footnote_1

10 *Ibid*

11 "Analysis: Vacationers Generate 8 Times More Carbon on a Cruise Ship than on Land", *Friends of the Earth*, 18 April 2023, https://foe.org/news/cruise-passengers-carbon/

12 Greenhouse Gas Emissions, *Seattle Cruise Control*, accessed 08 October 2023, https://seattlecruisecontrol.org/learn/greenhouse-gas-emissions/

13 Dijkstra Constance and Valentin Simon, "The Return of the Cruise – How luxury cruises are polluting Europe's cities", *Transport and Environment, European Federation for Transport and Environment AISBL, June 2023*, https://www.transportenvironment.org/wp-content/uploads/2023/06/The-return-of-the-cruise-June-2023.pdf

14 IMO 2020 sulphur limit implementation – carriage ban enters into force, *International Maritime Organisation*, 02 March 2022, https://www.imo.org/en/MediaCentre/PressBriefings/pages/03-1-March-carriage-ban-.aspx

15 Dijkstra Constance and Valentin Simon, "The Return of the Cruise", *Transport and Environment*, June 2023

16 Summary of Cruise Ship Waste Streams, Bureau of Transportation Statistics, last modified on 20 May 2017, https://www.bts.dot.gov/bts/bts/archive/publications/maritime_trade_and_transportation/2002/environmental_issues_table_01

17 "Ballast Water Management", International Maritime Organisation, https://www.imo.org/en/ourwork/environment/pages/ballastwatermanagement.aspx

18 Anderson Kirkland Robert , Tourism Impact on Environmental Sustainability: A Focus on the Cruise Industry , *IntechOpen, 2020*

19 "Cruise-Ship Pollution — Effects on Marine Life", *Friends of the Earth,* 21 December 2023, https://foe.org/blog/cruise-ship-effects-marine-life/

20 Vanderlaan Angelia SM and Christopher T Taggart, "Vessel Collisions with Whales: The probability of Lethal Injury based on Vessel Speed*", Marine Mammal Science*, ResearchGate, January 2007, https://www.researchgate.net/publication/227533035_Vessel_collisions_with_whales_The_probability_of_lethal_injury_based_on_vessel_speed

21 "Cruise Ship Pollution Effects on Marine Life", *Friends of the Earth,* December 2023

22 Anderson Kirkland Robert , Tourism Impact on Environmental Sustainability , IntechOpen, 2020

23 Haldar Stuti, Vandana Kapoor and Dr Indira Dutta, "Marine Tourism in India: A Journey towards Sustainable Development" (Conference paper, University of Oxford, London, March 2015), https://www.academia.edu/28053345/Marine_tourism_in_India_A_journey_towards_sustainable_development

24 The earlier coastline-length of 7,506.6 km has been revised and the current (as of 2023) figure, as per data from the office of India's National Maritime Security Coordinator (NMSC) within the National Security Council Secretariat (NSCS) is 11,804 km.

25 Draft National Strategy for Cruise Tourism, Ministry of Tourism, Government of India, June 2023

26 Government of India Press Release, "Cruise Tourism in India has the Potential to Grow Ten-fold says Shipping Minister Sarbananda Sonowal", Ministry of Ports, Shipping and Waterways, Government of India, 14 May 2022, https://pib.gov.in/PressReleasePage.aspx?PRID=1825354

27 Kotler Philip T and Gary Armstrong, "Principles of Marketing", 17th Global Edition, Pearson, July 2017

28 Draft National Strategy for Cruise Tourism, Ministry of Tourism, Government of India, June 2023

29 First "Incredible India International Cruise Conference [2022]", Ministry of Tourism, Government of India, 15 May 2022, https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1825607

30 Government of India Press Release, "Cruise Tourism in India has potential to grow 10-fold says Shipping Minister Sarbananda Sonowal", Ministry of Ports, Shipping and Waterways, Government of India, 14 May 2022, https://pib.gov.in/PressReleasePage.aspx?PRID=1825354

31 *Ibid*

32 Spotlight, Sagarmala Post 2020 Edition, March 2020, https://www.sagarmala.gov.in/sites/default/files/The%20Sagarmala%20Post%20%28March%29%202020%20Edition%20%28Spotlight%29.pdf

33 "Cruise Tourism in India", Government of India, 14 May 2022, https://pib.gov.in/PressReleasePage.aspx?PRID=1825354

34 "Sagarmala: Port Led Prosperity", *Maritime India Vision 2030*, Ministry of Ports, Shipping and Waterways, Government of India, February 2021, https://sagarmala.gov.in/sites/default/files/MIV%202030%20Report.pdf

35 "Cruise Tourism in India", Government of India, 14 May 2022, https://pib.gov.in/PressReleasePage.aspx?PRID=1825354

36 "Tourism in the 2030 Agenda", *World Tourism Organization (UNWTO)*, accessed on 05 August 2023, https://www.unwto.org/tourism-in-2030-agenda

37 Anderson Kirkland Robert, "Tourism Impact on Environmental Sustainability", *IntechOpen*, 2020

38 *Ibid*

The Implementation of the Notion of Seaport Tourism for Seaport Sustainability

Mr Mahendrran Selvaduray et al

Seaports are major gateways for the functioning of international trade and play an essential role in the growth of both developed and developing countries. Seaports are multifaceted, dynamic systems with numerous interacting elements.[1] The primary goal of a seaport business is to increase port throughput and maximize resource utilization, including the usage of berthing, quay crane operation, loading and unloading operations, warehousing, as well as the dry port role in the hinterland. The second goal is to reduce handling time, minimize port congestion, disruption, demurrage, and operational costs.[2] Shipping lines and shippers are the main customers for a seaport, and the role of a port operator is to sustain the customers by providing the services they require.[3] However, within the shipping industry, seafaring labour is a critical element determining the functioning of shipping operations and indirectly impacting port operations in terms of arrival, preparation for berthing, getting cargo ready for loading and unloading, and handling ancillary conservancy services from ports.

A study reported that 323 seafarers employed on 22 container ships were experiencing high-stress levels while contemplating their jobs onboard. The underlying causes being identified are sailing route, trip duration at sea, physical stressors (e.g., noise and seasickness), and psychosocial stressors (e.g., shift to a new ship). Furthermore, a study showed that depression, anxiety, general psychiatric disorders, and poor health status were major causes of stress in 439 multinational seafarers out of 470 seafarers[5]. It found that watchkeepers had significantly shorter sleeping periods than daytime workers in ships.[6] People with inadequate engagement in outdoor social activities were more likely to develop mental illnesses and have a negative impact on their health.[7] The operational constraints that seafarers face on board ships have caused unanticipated consequences on their health.[8] This highlights the need to address the mental health issues of seafarers in the shipping industry.

In addition, the Maritime Labour Convention in 2006 has developed a guideline on minimum working hours and living standards for all seafarers working on onboard to significantly improve the living and working conditions of seafarers. Nevertheless, the implementation was not maintained. This is due to the fact that the welfare of seafarers is still compromised in numerous ways, including social isolation, fatigue, stress, and the feeling that their occupation may be criminalised and targeted in many parts of the globe.[9] Apart from that, the noise and vibration during the voyage, environmental conditions, voyage cycle, not estimated number of port calls, and poor cargo handling hinder the seafarer's ability to obtain restful sleep.[10] Nevertheless, seafarers are also harmed by unethical crewing practises, including the use of unfair contracts, the abandonment of ship-owners, the delay or non-payment of their wages, the denial of shore leave, the inability to communicate with their families while onboard, and the refusal to repatriate them when their contracts expire.[11]

Inadequate maritime legislation pertaining to the welfare of seafarers indicates that a significant number of seafarers are owed enormous sums of money. In many instances, months pass with no signs of payment. Without pay, seafarers "*cannot even afford to escape and return home on their own*." The reduction of crew size has a significant impact on the living and working conditions of seafarers in the twenty-first century. Additionally, the crew reduction in the modern shipping industry is driven by technological advancement and the increased efficiency of larger vessels, as well as the desire of permanent shipowners to reduce labour costs. Nonetheless, in the name of business efficiency, ships typically operate with minimal crews, requiring seafarers to work long hours and for extended periods.[12] Since shipping is the only industry that operates non-stop, seafarers frequently work long and irregular hours. As a result, seafarer fatigue may be caused by the small number of crew members aboard commercial ships, as well as the extensive quantity and duration of work. Furthermore, shore leave or a short-term break is frequently rendered nearly impossible due to the isolation of modern ports. Historically, old ports like Liverpool, San Francisco, and Yokohama were situated close to city centres. However, new ports or modern ports are constructed 15–20 miles away from cities resulting in an absence of people, public transportation and welfare centres.[13]

The Concept of Seaport Tourism

The concept of maritime tourism has been initiated where port activities is not only limited to the port operation.[14] Maritime tourism has been segregated into three main areas, which are foreland, seaports and hinterland.[15] This is because, the port activities not only benefits the seaport itself but to the city and its regional development. To overcome the issues on seafarers' mental health, this short research note was designed to introduce a seaport leisure city on the bridge in the port limit. Figure 1 below depicts the idea of an illustration of the proposed concept of a seaport leisure city on the bridge in the port limit. Providing tourism activities during the lay hours will make the seafarers more relaxed and bringing energy to the next port of call. This is because, there is a strong relationship between travel, tourism, and mental health. Tourism activities could foster mental health and well-being among seafarers. Developing a tourism spot could improve the health and well-being of the seafarers.[16] The concept of developing a leisure city on the bridge in the port limit is still new. In light of the growing concern for seafarers' mental health during sea voyages, this research proposes that bringing in seaport tourism would be an effective solution. The leisure city should comprise many facilities, for example, of hospitality facilities package. It may include lodging, food services, event planning, theme parks, transportation, seaport museum and other tourism-oriented products and services to help the seafarers improve their mental health. The bridge concept is shown in Figure 1. The bridge will not interrupt any port operations, and it will function as a mini leisure-town within the port limit. While waiting for cargo to be discharged, seafarers could enjoy themselves in the leisure city. This will benefit both the port and the seafarers in addition to the local economy. This will also promote the port as a cruise port as the factors for port selection by cruise ships are also in line with the elements of the proposed leisure park on the bridge. The port can generate additional income, and the seafarers can improve their mental health and well-being. The concept proposed will assist in safeguarding the seafarer community as frontline workers in global trade from both short-term and long-term in terms of their well-being and the current high turnover. Vessel crews could be motivated by making their next port of call more pleasant while increasing their deal for work.

The Notion of Sustainable Seaports Through Utilisation of Inland Facilities

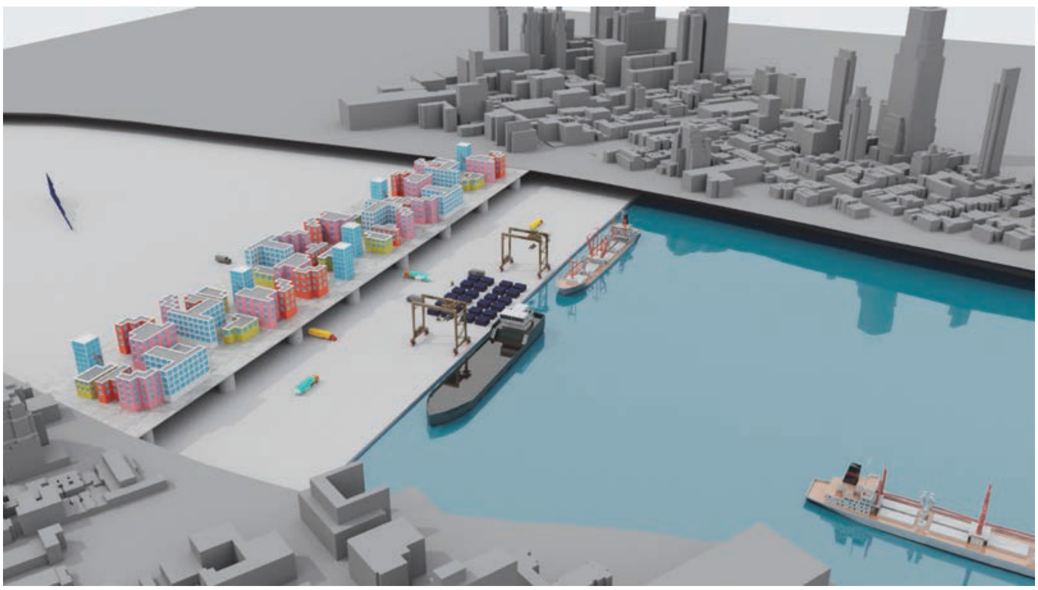
In the current trade system, the integration of seaports and inland components has become essential to ensure the competitiveness of seaports especially in the agenda of international trade. However, this cooperation is not effective in some seaports system due to the complexity and rigidness of seaport operations.[17] Consequently, limitation in strategies implementation, challenges in energy transformation, poor monitoring and evaluation systems, innovation barriers, low stage of development, cross-sectoral issues as well as lack of resources utilisation plan have been detected. Underpinned by these critical consequences, the inland ports are proposed to rebrand the seaports towards sustainable trade nodes. Besides enforcing these entities to cooperate, this paper has proposed a new dimension to ease the cooperation between them. The application of geologistics notion has been proposed to improve the sustainability of seaports in the complex business ambience. This concept focuses on the role of inland ports by identifying the resources, classifying the resources and coordinating the distribution of the resources for the benefit of mankind. In this situation, the assistance of inland ports is substantial to push the role of seaports in various locations in the specific country (regardless of whether the countries are coastal or landlocked).[18] The enforcement of this new dimension through inland ports may improve the strategies implementation, minimising energy transformation, monitoring and evaluation systems through information sharing, innovating in freight logistics, optimising stage of development in seaports, inspiring the horizontal and vertical integration as well as improving the resources utilisation. Owning to these outcomes, the sustainability of seaports is anticipated to improve especially on natural resources, capital resources, human resources as well as man-made or cultural resources.

This paradigm shift may diversify seaport operations in the future. For example, the introduction of geologistics application between seaports and inland ports, new seaport business is expected to grow and nourishing the volume of gross domestic product (GDP) in the particular nation.[19] In addition, the introduction of leisure city, port city, seaport based economic activities may provide significant impact on the inland economy of the country. The introduction of leisure city can be directed to the ship crews as well as professional and non-professional labour forces in the seaports. This is crucial for the labours to regain their motivation and energy in the leisure city which is located adjacent to the seaports.[20] The new role of inland ports through geologistics application may reduce the rigidness of seaports in the maritime business and they may diversify the nature of the business towards inland. In that case, the cooperation between inland ports and seaport will be prolific and nourishing the interaction of seaport-city especially through the new dimension of inland ports.[21]

Conclusion

The introduction of seaport tourism will not only reduce the mental stress of seafarers but also increase port competitiveness. A developed or developing seaport should

Figure 1: Depicts an illustration of the proposed concept of a leisure city on the bridge in the port limit



not only focus on port operations but also prioritize the mental health of its workers. A seaport should provide a happy and harmonious working environment, not a "Stress Seaport." By introducing seaport tourism, it will attract more ports of call from around the globe. This is because the new concept of seaport tourism will add value for maritime consumers, eventually impacting the seaport's competitiveness and the nation's Gross Domestic Product (GDP). Future studies will be conducted to identify significant factors that contribute to seaport tourism.

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ENDNOTES

1. Jeevan Jagan, Mahendran Selvaduray, Nurul Haqimin Mohd Salleh, Abdul Hafaz Ngah, and Suhaiza Zailani "Evolution of Industrial Revolution 4.0 in seaport system: An interpretation from a bibliometric analysis." *Australian Journal of Maritime & Ocean Affairs* 14, no 4 (2022): 229-250

2. Jaja, Chioma Y "Freight traffic at Nigerian seaports: Problems and prospects" Medwell Journals 6 (2011): 250-258

3. Salleh, Nurul Haqimin Mohd, Mahendrran Selvaduray, Jagan Jeevan, Abdul Hafaz Ngah, and Suhaiza Hanim Mohamad Zailani "Prioritizing the critical sustainable factors for the industrial revolution 4.0 in Malaysian seaports sector by using analytic hierarchy process" In AIP Conference Proceedings, vol 2484, no 1, p 030005 AIP Publishing LLC, 2023

4. Oldenburg, Marcus, and Hans-Joachim Jensen. "Stress and strain among seafarers related to the occupational groups." *International journal of environmental research and public health* 16, no 7 (2019): 1153

5. Baygi, Fereshteh, Nami Mohammadian Khonsari, Arash Agoushi, Saeed Hassani Gelsefid, Armita Mahdavi Gorabi, and Mostafa Qorbani "Prevalence and associated factors of psychosocial distress among seafarers during COVID-19 pandemic." *BMC psychiatry* 21, no. 1 (2021): 222

6. Lucas, David, Camille Jego, Olaf Chresten Jensen, Brice Loddé, Richard Pougnet, Jean-Dominique Dewitte, Thierry Sauvage, and Dominique Jegaden. "Seafarers' mental health in the COVID-19 era: lost at sea?." *International maritime health* 72, no. 2 (2021): 138-141

7. Sundarasen, Sheela, Karuthan Chinna, Kamilah Kamaludin, Mohammad Nurunnabi, Gul Mohammad Baloch, Heba Bakr Khoshaim, Syed Far Abid Hossain, and Areej Sukayt. "Psychological impact of COVID-19 and lockdown among university students in Malaysia: implications and policy recommendations." *International journal of environmental research and public health* 17, no. 17 (2020): 6206

8. Zhou, Shuang-Jiang, Li-Gang Zhang, Lei-Lei Wang, Zhao-Chang Guo, Jing-Qi Wang, Jin-Cheng Chen, Mei Liu, Xi Chen, and Jing-Xu Chen "Prevalence and socio-demographic correlates of psychological health problems in Chinese adolescents during the outbreak of COVID-19" *European child & adolescent psychiatry* 29 (2020): 749-758

9. Exarchopoulos, Georgios, Pengfei Zhang, Nicola Pryce-Roberts, and Minghua Zhao. "Seafarers' welfare: A critical review of the related legal issues under the Maritime Labour Convention 2006" *Marine Policy* 93 (2018): 62-70

10. Alderton, Tony, Michael Bloor, Erol Kahveci, M. Zhao, T. Lane, H. Sampson, Nik Winchester, M. Thomas, and Bin Wu. The global seafarer: Living and working conditions in a globalized industry. *International Labour Organization*, 2004

11. Nguyen, Trong Thanh, Hadi Ghaderi, Livingstone Divine Caesar, and Stephen Cahoon "Current challenges in the recruitment and retention of seafarers: an industry perspective from Vietnam" *The Asian Journal of Shipping and Logistics* 30, no 2 (2014): 217-242

12. Jeevan, Jagan, Nurul Haqimin Mohd Salleh, Izyan Munirah Mohd Zaideen, Mohamad Rosni Othman, Masha Nur Salsabiela Menhat, and Livingstone Divine Caesar "Application of geoeconomics in seaport operations: a theoretical proposal for post Covid-19 recovery strategy" *Australian Journal of Maritime & Ocean Affairs* 12, no 4 (2020): 217-242

13. Alderton, International Labour Organization, 2004

14. Jeevan, Jagan, Mohamad Rosni Othman, Zuha Rosufila Abu Hasan, Thi Quynh Mai Pham, and Gyei Kark Park "Exploring the development of Malaysian seaports as a hub for tourism activities." *Maritime Business Review* (2019)

15. Selvaduray, Mahendrran, Yapa Mahinda Bandara, Rosmaizura Mohd Zain, Ainon Ramli, and Mohd Zaimmudin Mohd Zain "Bibliometric analysis of maritime tourism research" *Australian Journal of Maritime & Ocean Affairs* (2022): 1-27

16. Marmion, Maeve, and Ann Hindley "Tourism and health: Understanding the relationship" *Good health and well-being* (2020): 738-746

17. Jeevan, Jagan, Rosni Othman, Madzli Harun, Mahendrran Selvaduray, and Rosmaizura Mohd Zain. "Incorporation of Dry Ports into the National Transport Policy: A Proposal for International Trade Acceleration." *Transactions on Maritime Science* 12, no. 1 (2023)

18. Ngah, Abdul Hafaz, Ramayah Thurasamy, Nurul Haqimin Mohd Salleh, Jagan Jeevan, Rudiah Md Hanafiah, and Bilal Eneizan "Halal transportation adoption among food manufacturers in Malaysia: the moderated model of technology, organization and environment (TOE) framework" *Journal of Islamic Marketing* 13, no 12 (2022): 2563-2581

19. Salleh, Nurul Haqimin Mohd Salleh, Rudiah Md Hanafiah, Abdul Hafaz Ngah, Jagan Jeevan, Lazim Abdullah A Framework Proposal for Evaluating the Organizational Reliability and Capability of a Liner Shipping Operator in a Fuzzy Context Special Issue, 8(6S3), pp 327–341

20. Salleh, Nurul Haqimin Mohd, Nur Ain Solehah Abd Rasidi, and Jagan Jeevan "Lean, agile, resilience and green (LARG) paradigm in supply chain operations: a trial in a seaport system" *Australian Journal of Maritime & Ocean Affairs* 12, no 4 (2020): 200-216

21. Selvaduray, Mahendrran, Mohammed Ismail Russtam Suhrab, Raja Somu, Jagan Jeevan, Nurul Haqimin Mohd Salleh, and Rosmaizura Mohd Zain. "The fourth industrial revolution: a catalyst for regional development in Malaysian seaport sector." *Australian Journal of Maritime & Ocean Affairs* (2022):1-12

A Study of Critical Sustainable Factors in the Malaysian Seaport Sector for the Implementation of Industrial Revolution (IR) 4.0

Mr. Nurul Haqimin Mohd Salleh and Mr. Mahendrran Selvaduray

As the world accelerates its adoption of Industrial Revolution (IR) 4.0 and embraces the digital economy, players in the maritime industry must remain informed with technological trends in accordance with the change and thrive in the digital era. To accomplish this, a comprehensive approach is required to bring stakeholders up to pace with the globalist agenda shaped by IR 4.0.[1] The German government became acquainted with the latest Industrial Revolution mechanism in November 2011, which it believes will shake up the maritime industry. IR 4.0 has been demonstrated to have a positive impact on the global industrial sector.[2] The maritime industry plays an essential role in a nation's economic development.

Malaysia is a Southeast Asian country with a strategic location along the Strait of Malacca, which serves as a major sea route connecting the Far East to Asia, Europe, and the Middle East. Malaysia as a maritime nation has always relied on maritime trade. Malaysia will not be able to thrive in the maritime sector solely because of its location. As a result, a global standardisation framework must be established to ensure the efficacy and long-term implementation of IR 4.0 strategic and inventiveness in the Malaysian seaport industry. Most stakeholders are still hesitant to spend a significant amount of money on IR 4.0 without knowing what benefits they will reap in the future.[4] Most of the reasons for this are that organisations lack a proper organisational strategy for implementing IR 4.0.[5] The most difficult challenge to implementing IR 4.0 is an absence of a coherent strategy for creating value, as well as a lack of leadership support. Malaysia highly depends on national ports to facilitate trade and economic development as the main ports to this maritime trade. Seaports are major players in the international supply chain.[6]

As a result, seaport competitiveness and profitability would be critical for ensuring the smooth operation of foreign trade. Nonetheless, the introduction of IR 4.0 in early 2010, at the beginning of the age of immersive digitization, demonstrated that the maritime industry, for example, the seaport sector, must be prepared to meet unexpected developments in dynamic maritime commerce.[7] The subject of IR 4.0 is still understudied, even though research on it has grown tremendously in recent years.[8] The goal of this research is to determine the most important Critical Sustainable Factors (CSFs) for implementing IR 4.0 in Malaysian seaports. CSFs must be considered as a critical component in the sustainable implementation of Malaysian seaports. Given that digitalization is a critical component of the maritime industry's future, not only in terms of operational and technical aspects, but also in terms of implementing the IR 4.0.[9] Based on the literature, this study discusses several potential CSFs that may influence the implementation of IR 4.0. A conceptual model will be developed in future research to illustrate the CSFs outcomes in IR 4.0 implementation at the seaport industry, which will contribute to the eventual development of a decision-making guideline.

Industrial Revolution 4.0

The term "Industrial Revolution (IR) 4.0" refers to new technologies such as the Internet of Things (IoT), Big Data, and Cyber-Physical Systems (CPS) (CPS). Computers, automation, and robots have existed for decades, but the internet has revolutionised their use and opportunities.[10] IR 4.0 is transforming corporate structures and practises, reshaping business strategies, and boosting customer satisfaction.[11] Furthermore, it is the same in the seaport industry, which starts with the arrival of the ship. Ships calling at the port will be received based on community circles. As soon as a ship is within range of a terminal, a harbour coordination centre, vessel traffic managers, tug masters, and pilots form a technology circle. All same principles are applicable on a shipment level, and it ends with the ship's departure.[12]

It accelerates communication developments by using a Cyber-Physical System (CPS). As a result, businesses will find it easier to establish global networks that integrate warehousing systems and run CPS seaports.[13] Without a doubt, CPS in maritime aims for the tight integration of wireless communications, control, and computing technologies into the navigation transportation system, which possesses the typical CPS characteristics of revolutionising the navigation pattern to be safer and more efficient through real-time embedded systems for distributed sensing, computation, and control between cyber and physical systems.[14]

The Internet of Things (IoT) can commonly provide advanced system, service, and physical object connectivity, allowing for object communication and data sharing. IoT can be achieved in a variety of industries by controlling and automating aspects such as remote control.[15] The development of global trade and globalisation has resulted in a noticeable trend in traffic and cargo, obliging numerous seaport ports to accept changes and use the (IoT) in their seaports for more effective practises. Big Data has recently become a hot topic in IR 4.0. Importantly, big data refers to the use of digital technology to conduct analysis.[16] In port terminals, we have very big amounts of data generated by the hour. Some examples of these data are ships that are being serviced, types of cargo stored within the terminal, current productivity of the equipment and workers, out-and inbound traffic, payment and billing information and details, cargo loading and unloading deadlines, ongoing contracts, etc. All this information can be stored in real-time in Data Warehouses, because it constitutes Big Data, that will ultimately help the Terminal grow.[17]

Critical Sustainable Factors

There is no clear consensus on the concept of sustainable development, but the most generally recognized interpretation is the following: "to provide for the needs of the present generation without compromising the abilities of future generations to meet their needs".[18] In contrast, most of the sustainable development taken into consideration and find a balance among economic, social, and environmental factors, which are also referred to as the triple bottom line.[19] In this research, the identification of Critical Sustainable Factors (CSFs) for the implementation of IR 4.0 appears to focus on the additional narrow dimension such as political and legal, communication and cooperation, and operational and technical qualities These dimensions are extended the "Triple Bottom Lines" strategy.[20] Additionally, there are many issues in maritime ports and related activities that are constantly emerging and becoming a competitive factor. CSFs has thus become a major research focus and continues to attract the attention of many scholars for sustainable implementation.[21] In this study, researchers had identified the main dimension along with the CSFs which will influence the implementation of IR 4.0 in Malaysia seaports.

Environmental Protection

The environmental sustainability of the ports has been a matter of concern to the port users, policymakers, port authorities, and the local community. For ensuring sustainable development, environmental protection was promoted by international and national legislation. As well as that, the industrial businesses be required to realize that environmental responsibility should be included in the company policies.[22] The port environment including the channels of entry, water management, dredging, beaches, soil, and other natural areas be required to be protected.[23] Owing to the appropriate use of the resources, a decrease in energy consumption, waste reduction, waste recycling, and a lower release of poisonous gases. This was possible when the technological innovations were related to the sustainability of a country wherein the environmental-based technological changes improve the environmental quality.[24]

Waste minimization was described as a technique for removing wastes like the defects which needed reprocessing, transport of goods and people, excessive processing.[25] Some seaport operations use a lot of energy and hazardous materials or generate solid waste which can pollute the environment. Besides, Malaysia is facing a problem with marine derbies, for example, plastic pollution. Artificial Intelligence (AI) drones can help to identify the waste, for example, plastics, oil spills, and company waste. By using this, we can easily identify and measures the obstacles at the seaport, this shows the advantages of IR 4.0. AI in maritime technologies have undergone a significant change after the introduction of IR 4.0.[26]

The consumption of natural resources is a matter of great concern to the port authorities. The ports have realized the importance of acquiring a green status by using novel technologies, redesigning their infrastructure, and preventing the massive consumption of energy.[27] Renewable energy was seen to a vital component in the maritime sector, since this sector aimed to reuse the electronic wastes to minimize their environmental effect.[28] Waste recycling refers to the processing of used materials or wastes to develop useful and novel products. IR 4.0 could help in reducing the use of raw materials for developing new products. It also requires lesser energy and was seen to be an effective technique for controlling water, air, and land pollution at the seaports.[29]

Social Equity and Culture

The shipping companies focus primarily on balancing the main concerns of the employees such as their health and safety during work, their well-being, and job satisfaction, providing incentives for improving the skills of the workers while transferring the new knowledge related to IR 4.0.[30] The employees are seen to be more successful in their work and are more dedicated to the shipping business if all standards are successfully met.[31] The Internet of Things (IoT) is a novel concept that has revolutionized all lives and society. This concept was developed for connecting the objects to a network, which helped the people access all the global information. The employees must consider the trade-offs for promoting the "digital trust" amongst the working staff if they attempt to collect all data at their workplaces. This is necessary for understanding the actual benefits of the IoT and actual sharing of the information.[32] The workers have to be more ready to adopt novel technologies of IR 4.0 which helps in preserving competitiveness and offers them a competitive advantage in the maritime industry.[33]

Cloud Computing in IR 4.0 has helped in making the information more transparent by significantly increasing the number of objects and individuals who are interconnected. A virtual copy of the world could be generated by linking all sensor data and the digitized plant models. Hence, the results of the data analytics should be included in the support systems which can present all the IR 4.0 characteristics.[34] All the data related to the port operations are made transparent and then it is optimized for improving the usage of productive equipment, developing optimized energy schedules, and saving energy.[35] IR 4.0 could embrace the transition expertise, work-task rotation, make all work-related adjustments (i.e., uncertainty tolerance), including the versatility of time and position, and the different leadership skills during the different seaport operations.[36] Developmental techniques could affect the tasks related to the engineering design behavior, research areas and development of cost-effective, Research and Development (R&D) project. Furthermore, the use of a digitization strategy provided a solution to the ports which helped them achieve a competitive advantage and increase their competitiveness.[37]

Economical Values

IR 4.0 offered a near-real-time accuracy of the various port operations and improved their economic performance. The Cyber-Physical System (CPS) can reduce the cost due to interconnection played a vital role, fed knowledge, and added value to the maritime industries so that they operated in a cost-effective manner.[38] Furthermore, the interconnection between objects, humans, and systems has led to the creation of a real-time optimized, dynamic, and self-organized inter-company value system, which is optimized and evaluated using criteria like resource efficiency, costs, and availability. IR 4.0 is a lean process that presented cost-effective logistics, which could be fulfilled by the managers who planned efficient operations for decreasing the stocks, decreasing the lead times, reducing the number of resources, hiring fewer employees, eliminating the non-value adding operations, decreasing redundant efforts and removing all wastes from the seaport operations.[39]

Shipbuilding industries are a major activity carried out in the maritime ports. Shipbuilding 4.0 refers to a digitization process included in IR 4.0, which contributed significantly to the economy. It was stated that this technique would save 15% additional costs compared to the conventional shipbuilding techniques.[40] The company-level technology users of IR 4.0 ought to improve their capacity utilization and rapidly market their products, according to the changing needs of the market. Adaptability and the IT changes were seen to be important achievement variables affecting an assembly process, which can influence financial performance.[41] Implementation of the IoT has offered many cost-reducing benefits to several organizations. IR 4.0 provides a real-time precision, enables a cross-sectional plant optimization of port services, and improves the economic output.[42]

Operational Value and Technical Qualities

IoT was complemented by the Internet of Services (IoS) since the smart services offered their abilities as an intelligent service. The application of such technologies presents many technological improvements and advantages. IR 4.0 is giving a higher utilization rate of resources, and it can be considered as one of the lean principles which make, the seaport operations more convenient and fluently.[43] IR 4.0 helps in improving the efficiency of resource usage while also reducing while balancing the resource utilization in the environment which is affected by the destruction of the seaports or pollution. The use of resources at the ports indicates the application of various equipment related to the vessel arrival times and rates during the seaport operations. The usage metrics estimate the rate of use of different port facilities, i.e., the occupancy rate of berths and the yard usage compared to the actual usage of the seaport services.[44]

Just-in-Time (JIT) Practices, is an IR 4.0 activity which follows the lean approach and is mainly pull-oriented, indicating that the material was produced and supplied only in the case of real demand. JIT is a novel technique that increases productivity and decreases wastes by acquiring the products only when the inventory decreases, which reduces expenses.[45] The increasing use of Information Technology (IT) has made the system more efficient, faster, cost-effective, and allowed a reliable development of the information-related transport services in a maritime port sector. IR 4.0 implements the ICT processes, such as digitization and automation, for improving the seaport operations.[46] IR 4.0 has offered many administrative-efficiency processes, which help in decreasing administrative and documentation activities. Cloud data storage is one of the best examples from the IR 4.0, which makes the seaport operations more reality without any interruption. More, the smart machines which use as self-configuration, self-optimization, or man-made optimization for completing tasks are required to offer better services during the port operations.[47] IR 4.0 makes all services safer, flexible, and effective. Furthermore, IR 4.0 improved the efficiency and transparency of the management decisions and processes since the real-time data was made available for all the port operations.[48]

Communication and Cooperation

Cooperation and communication were the major components that were involved in the knowledge and information sharing along with partnering with the main players. The research on the sustainability of the port operations stated that cooperation and involvement of the stakeholders was the main factor that helped the ports become more sustainable.[49] Early cooperation was needed between the stakeholders for implementing sustainable development activities. The successful implementation of the IR 4.0 activities was based on how the workers responded to the various IR 4.0 activities. Organizational readiness is based on communication, organization, and decision-making initiatives.[50] The vision, mission, and direction of a company must allow the implementation of novel technologies by the seaport operators, who are familiar with the IR 4.0 processes. The port authorities usually encourage the shipping companies to decrease waste and pollutant emissions at the ports. This was the major initiative undertaken by the port authorities for implementing the IR 4.0 activities at the seaports. They work with the shipping companies for eliminating their environmental issues by conducting business meetings and introducing relevant regulations/rules or campaigns.[51]

The implementation of the IR 4.0 principles in the organizations of the shipping lines can affect the deep structure of the organizations owing to their horizontal, vertical, and end-to-end integration. Furthermore, this changes the primary assumptions regarding the management processes since the existing business practices have started implementing the principles of digitization and automation.[52] The culture of the organization and other systems is also altered after the introduction of the IR 4.0 principles. Freight forwarders used digitization in their real-time activities for increasing the consistency of their planning, operation, management, control, and coordination activities for different tasks. One of the first factors which are considered in IR 4.0 is strategic management using an operational approach for maritime ports. The company strategy acts as a guide for various business decisions. The short and long-term success of the company is based on the performance of its operational strategies.[53]

Political and Legal Parameters

The government ministries have formulated and implemented many industrial schemes and rules for developing novel business models which are based on the growth requirements or objectives of the countries. There is an increasing pressure to enhance the digital civilization of the seaport operators, along with different circumstances that encourage the financial growth of the company and society. For preventing risks to the workers after the implementation of the digital transformation process, the company management needs to involve them in the early planning processes. IR 4.0 allows for a flexible replica of the working time.54 The workers, management, and the representative groups need to define arrangements which make the work hours more flexible while taking into consideration issues like the time enforcement and the restrictions on the overtime policies in the shipping and maritime sector.55

Furthermore, the skills of the existing workforce need to be assessed for understanding the emerging digital technology era. Many changes implemented in the intellectual property laws have altered the market strategies and made them more liberal and global. This also led to the initiation of new activities which encouraged the maritime organizations to develop their Intellectual Property Rights. IR 4.0 significantly affected intellectual property protection laws. The IR 4.0 encourages organizations to make several efforts for mastering the legal reforms related to IT security, data privacy, labor laws, and liability after the digital conversions. Company should be responsibility for the accidents and damages resulting due to the use of the autonomous vehicles.[56]

From the outcome of the comprehensive literature review, in total, 6 main dimensions and 36 critical sustainable factors are identified as critical to IR 4.0 implementation. Based on the sub section 2.2.1 - 2.2.6, Table 1 summarizes the 36 CSFs for the implementation of IR 4.0 in Malaysian seaports.

Table 1. Summary of literature review on critical sustainable factors

Critical Sustainable Factors	References
Environmental Protection	
Waste Minimisation	Mrugalska & Wyrwickah, 2017; Rasidi *et al*., 2019; Roh *et al*., 2016
The efficiency of Natural Resource Consumption	Chiu *et al*., 2014
Renewable Energy Initiatives	Kuhl *et al*., 2016
Environmental Impact Minimisation	Kuhl *et al*., 2016; Bonilla *et al*., 2018;
Waste Reuse	Kuhl *et al*., 2016; Rasidi *et al*., 2019
Waste Recycling	Chiu *et al*., 2014; Barquet *et al*., 2016; Kuhl *et al*., 2016
Social Equity and Culture	
Employees' Trust on the Internet of Things	Schuh *et al*., 2014; Jayashree *et al*., 2019
Employee's Acceptance of IR 4.0 Technologies	Schuh *et al*., 2014; Jayashree *et al*., 2019
Employee's Expertise for the IR 4.0 Technologies	Hareide *et al*., 2018
Data Transparency owing to the IR 4.0 Implementation	Hermann *et al*., 2016; Vaidya *et al*., 2018
Demographic Transition and Social Changes with the adoption of IR 4.0	Singh, 2018
Research and Development Culture Required for the implementation of IR 4.0	Singh, 2018; Oh *et al*., 2018
Economical Value	
Cost Reduction through the Interconnection	Bahrin *et al*., 2016
Non-value-adding Effort Reduction	Waters, 2007
Maintenance and Operational Costs of the IR 4.0 Technologies	Stani *et al*., 2018
IR 4.0 Technologies Replacement Costs	Bonilla *et al*., 2018; Mrugalska & Wyrwicka, 2017
Cost and Benefits of IR 4.0 Implementation on the Seaports	Haddud *et al*., 2017
Economic effectiveness of the IoT	Singh 2018
Operational Value and Technical Qualities	
Higher Utilisation Rate of Resources	Zhou *et al*., 2016; Rasidi *et al*., 2019; Salleh *et al*., 2017
Shorter Lead-Time	Rasidi *et al*., 2019; Ha *et al*., 2017
Just-in-Time (JIT) Practices	Singh & Ahuja, 2012; Rasidi *et al*., 2019
Information Spreading through the Network	Rasidi *et al*., 2019; Bahrin *et al*., 2016
Documentation and Administration Reduction	Müller *et al*., 2018
Service Flexibility Enhancement	Bahrin *et al*., 2016; Roblek *et al*., 2016); Müller *et al*., 2018

Communication and Cooperation	
Readiness of the Seaport Operators for the implementation of IR 4.0	Sony & Naik, 2019; Schuh *et al.*, 2014; Jayashree *et al.*, 2019
Readiness of the Seaports Authorities to Implement the IR 4.0 principles	Roh *et al.*, 2016
Cargo-owners' Acceptance Related to the IR 4.0 Implementation by the Seaports	Sony & Naik 2019
Shipping Lines Acceptance of the IR 4.0 Implementation by the Seaports	Ancarani *et al.*, 2019; Manavalan & Jayakrishna, 2019; Sony & Naik, 2019
Freight forwarders' Acceptance of the IR 4.0 Implementation by Seaports	Sony & Naik, 2019
Align the Implementation of the IR 4.0 principles with the maritime port organisational strategy	Sony & Naik, 2019
Political and Legal	
Government enhancement in the shipping industries	Schroeder & Bigdeli, 2018; Singh, 2018; Oh *et al.*, 2018
The role of Maritime Administration and the Ministry of Transport	Singh, 2018; Yunus & Yang, 2012 Sony & Naik, 2019
Social-democratic pressure on the digital culture	Singh, 2018; Schroeder & Bigdeli, 2018
Onboard working policies and labour laws	Bhattacharjea, 2006; Singh, 2018
Intellectual property rights in the Shipping and Maritime Industries	Basant, 2004; Singh, 2018
Liability and Regulations for the autonomous devices and machines used by the seaport operators	Singh, 2018

Source: Compiled by Author

The finding in Table 1 above can conclude that, the literature had shown there can be further investigate on the "Triple Bottom Line" sustainability. Operational Value and Technical Qualities, Communication and Cooperation, Political and Legal Parameters are the main dimension which is an extension for the normal sustainability concept. There are 6 major dimension which indicates the sustainable implementation of IR 4.0 in Malaysian seaports. Moreover, these findings addressing the research questions on: What are the most critical sustainable factors for the implementation of Industrial Revolution 4.0 in Malaysian Seaports.

Methodology

To identify the most Critical Sustainable Factors by using the Compatibility Analysis, there are six steps needed to be followed:

Step 1: Identifying Critical Sustainable Factors by using literature review.

Step 2: CSFs were validated by expert consultation.

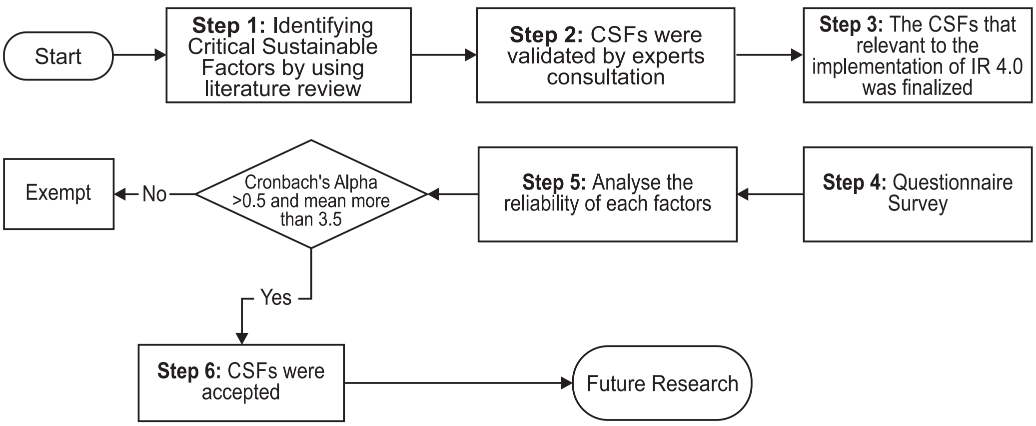
Step 3: The CSFs that relevant to the implementation of IR 4.0 were finalized.

Step 4: Paper-based questionnaire surveys were distributed again to the experts.

Step 5: The reliability of each CSFs was tested.

Step 6: Cronbach's Alpha more than 0.5 and the mean value of more than 3 were accepted for future study.

Figure 1 : Compatibility Analysis of IR 4.0 Implementation



Source: Author

Figure 1 identifies the most Critical Sustainable Factors for IR 4.0 implementation, the methods (i.e., Compatibility Analysis) were used. The CSFs are first identified from the secondary data (literature review). Then, factors validation through an expert's consultation. After the expert's validation, the CSFs that relevant to the implementation of IR 4.0 were finalized. In this study, the data was collected by a structured questionnaire. "Questionnaire is a popular method of collecting data because researchers can gather information fairly easily and the questionnaire responses are easily coded".[57] A paper-based survey comprising a closed-ended questionnaire was used to collect the data. The quantitative data are gathered from 38 maritime domain experts-i.e., academic researchers, strategy managers, and senior executives of the port operators from Malaysian seaports with over 10 years of experience in managing seaport operations. The experts were given equal chances to answer the designed questionnaire by evaluating and rating the compatibility of CSF for the implementation of IR 4.0. After that, the reliability of each CSFs was tested, and the mean value had been calculated. Cronbach's Alpha more than 0.5 and the mean value of more than 3.5 were accepted for future study.[58]

Analysis of Findings and Discussion

In designing the questionnaire, the outcomes from the comprehensive literature review were used. The paper-based questionnaires contain five-point scale Likert-type questions. Likert scale starts from 1 (strongly disagree) to 5 (strongly agree). The main reason for choosing a Likert scale is because it reflects the level of agreement on the importance of certain constructs and dimensions which is important for the implementation of IR4.0 in Malaysian seaports. Secondly, it provides the optimal length of rating to maximize the reliability and validity of the results. In total, 41 questions were generated for the questionnaire, grouped into two different sections-i.e., Section A: Respondent's background and Section B: Critical Sustainable Factors for IR 4.0 implementation. All the questions were generated precisely to answer the research question and only consume approximately 15–20 minutes of the respondent's time. This strategy reduces the length of the survey, reduces the amount of time needed for respondents to answer the questions, and increases the response rate.

The CSFs are filtered by choosing them with a 3.5 mean value and above. The CSFs which are lower score than 3.5 will be exempted. The results had been shown below in Table 3. Generally accepted rule is that 0.6-0.7 alpha value indicates an acceptable level of reliability, and 0.8 or greater a very good level. However, values higher than 0.95 are not necessarily good, since they might be an indication of redundancy. It cannot be denied 0.5 alpha value can be considered to be moderately reliable.[59] This section disclosed the findings of the paper-based survey with 38 experts. Apart from that, this section will also give the analysis of the demographic information of 38 experts, followed by results of compatibility analysis and discusses the findings. Table 2 summarize the CSF with average value for each criterion.

Table 2. Summary of CSFs with average value for each criterion

Factors	Cronbach's Alpha	Mean	Standard Deviation
Environmental Protection	0.506		
Waste Minimisation		4.08	0.487
Efficiency of Natural Resource Consumption		4.08	0.632
Renewable Energy Initiatives		4.03	0.592
Environmental Impact Minimisation		3.92	0.587
Waste Reuse		3.76	0.820
Waste Recycling		3.68	0.842
Social Equity and Culture	0.551		
Employees' Trust on the Internet of Things		3.71	0.732
Employee's Acceptance of IR 4.0 Technologies		3.87	0.665
Employee's Expertise for the IR 4.0 Technologies		4.08	0.632
Data Transparency owing to the IR 4.0 Implementation		3.84	0.823
Demographic Transition and Social Changes with the adoption of IR 4.0		3.87	0.623
Research and Development Culture Required for the implementation of IR 4.0		4.29	0.611
Economical Value	0.805		
Cost Reduction through the Interconnection		3.76	0.943
Non-value-adding Effort Reduction		3.63	0.714
Maintenance and Operational Costs of the IR 4.0 Technologies		3.55	0.891
IR 4.0 Technologies Replacement Costs		3.95	0.804
Cost and Benefits of IR 4.0 Implementation on the Seaports		3.97	0.592
Economic effectiveness of the IoT		4.03	0.716
Operational Value and Technical Qualities	0.795		
Higher Utilisation Rate of Resources		3.63	0.786
Shorter Lead-Time		3.82	1.010
Just-in-Time (JIT) Practices		3.92	0.941
Information Spreading through the Network		4.03	0.822

Documentation and Administration Reduction		3.95	0.655
Service Flexibility Enhancement		4.05	0.733
Communication and Cooperation	0.786		
Readiness of the Seaport Operators for the implementation of IR 4.0		4.16	0.679
Readiness of the Seaports Authorities to Implement the IR 4.0 principles		4.24	0.714
Cargo-owners' Acceptance Related to the IR 4.0 Implementation by the Seaports		3.95	0.567
Shipping Lines Acceptance of the IR 4.0 Implementation by the Seaports		4.13	0.529
Freight forwarders' Acceptance of the IR 4.0 Implementation by Seaports		3.87	0.623
Align the Implementation of the IR 4.0 principles with the maritime port organisational strategy		4.18	0.692
Political and Legal Parameters	0.775		
Government enhancement in the shipping industries		4.24	0.675
The role of Maritime Administration and the Ministry of Transport		4.45	0.795
Social-democratic pressure on the digital culture		3.87	0.529
Onboard working policies and labour laws		3.79	0.704
Intellectual property rights in the Shipping and Maritime Industries		4.05	0.695
Liability and Regulations for the autonomous devices and machines used by the seaport operators		4.16	0.638

Source: Author

The following formula used to calculate the mean value.

$$\bar{x} = \frac{\Sigma fx}{\Sigma f}$$

$\bar{x}\bar{x}$ is the average value,

f is the number of occurrences,

Σfx is the sum of the product fx,

Σf is the total number of occurrences.

Cronbach's Alpha reliability analysis was conducted to measure the internal consistency of the two constructs (see Table 3). This Cronbach's Alpha value were calculated from Statistical Package for Social Sciences (SPSS). SPSS is a statistical program that is developed by the IBM company and commonly used by researchers or academics around the world. This statistical program is very user-friendly and numerous statistical tests could be carried out using this programme. In the form of univariate, bivariate and multivariate analyses, both parametrical and non-parametric statistical techniques are performed for comparison and correlation statistical examination.

The demographic information from the survey was used to review the characteristics of experts. Table 3 presents a summary of the experts' work positions and the years of experience that they had in their respective fields. Out of the 38 experts, 9 (23.7%) were senior lecturers, 20 (52.6%) were executives and another 9 (23.7%) were companies' manager. The responses from these groups are expected to produce significant findings for this research. In respect to the experts' working experience, almost (50%) of them possessed 15 to 20 years of experience in their respective fields, while experts having work experience between 10 to 14 years are 39.5% of them. In total, 10.5% of the experts had more than 20 years of work experience in the maritime sectors. None of them who have a working experience of less than 10 years were chosen. Experts with more working experiences are expected to provide more precise information than those with fewer experiences, which ensures the quality of the research. Apart from that, the education background had considered for this research. More than 50% experts having a bachelor's degree, while another half of them had their master's and Doctoral Degree. A paper-based questionnaire survey is effective only when experts have knowledge of the topic and they are competent to answer the questions.

Based on the results above, economic value dimension is becoming a driving force in the globalization of sustainable development. This is because, it has the greater value of Cronbach's Alpha with 0.805. The assessment of the economic value dimension of a seaport is an important subject for both the political and the public debate. Seaport is considered a determinant of economic growth; it contributes to private sector development and economic gain. By implementing IR 4.0, it enhances the service quality of the seaport business and the operation sector. It has been noted that port sector investment can sustain the implementation of IR while it helps to economic growth of a nation. The Internet of Things (IoT) adoption has the potential to enhance operating processes, to reduce costs and risks due to its adaptability and versatility. IR 4.0 helps to boost economically and cutting down the operational costs.

Table 3. Summary of expert demography

No.	Position	Response	Percentage (%)
1.	Senior Lecturer	9	23.7
2.	Manager	9	23.7
3.	Executive	20	52.6
No.	**Experience**	**Response**	**Percentage (%)**
1.	0-9 years	0	0
2.	10- 14 years	15	39.5
3.	15- 20 years	19	50.0
4.	than 20 years	4	10.5
No.	**Education**	**Response**	**Percentage (%)**
1.	Bachelor's Degree	20	52.6
2.	Master's Degree	9	23.7
3.	Doctoral Degree	9	23.7

Source: *Authors*

Conclusion

This study concludes that, six main dimension and 36 critical sustainable factors are identified as critical for the implementation of IR 4.0 in Malaysian seaports. This paper has conducted an extensive literature review in the field of maritime sectors to identify the CSFs affecting the IR 4.0 implementation. Therefore, future research can significantly investigate those CSFs that could give a positive or negative impact on the implementation of IR 4.0 in the Malaysian maritime industry. A Focus Group Discussion (FGD) can conduct to enhance the quality of the CSFs with the more stakeholders, port operators and government agencies. Moreover, Analytical Hierarchy Process (AHP) method can be applied in this study to rank and prioritize the CSFs. Exploratory Factor Analysis (EFA) approaches can be conducted to explore and validate the relationship among the factors influencing the implementation of IR 4.0 in Malaysian seaports.

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ENDNOTES

1 N. Khalid, "Malaysia's Maritime Industry: Transitioning to Industry 4.0." *Selangor, Malaysia: myForesight* 2018: 7-11

2 Bahrin, Mohd Aiman Kamarul, Mohd Fauzi Othman, Nor Hayati Nor Azli, and Muhamad Farihin Talib, "Industry 4.0: A review on industrial automation and robotic," *Journal teknol* 78, no. 6-13 (2016)

3 Zhou, Keliang, Taigang Liu, and Lifeng Zhou. "Industry 4.0: Towards future industrial opportunities and challenges." In 2015 12th International conference on fuzzy systems and knowledge discovery (FSKD), pp. 2147-2152. IEEE, 2015

4 Jeevan, Jagan, Nurul Haqimin Mohd Salleh, Izyan Munirah Mohd Zaideen, Mohamad Rosni Othman, Masha Nur Salsabiela Menhat, and Livingstone Divine Caesar. "Application

of geoeconomics in seaport operations: a theoretical proposal for post Covid-19 recovery strategy," *Australian Journal of Maritime & Ocean Affairs* 12, no. 4 (2020): 217-242

5 Sony, Michael, and Subhash Naik. "Critical factors for the successful implementation of Industry 4.0: a review and future research direction." *Production Planning & Control* 31, no. 10 (2020): 799-815

6 Selvaduray, Mahendrran, Mohammed Ismail Russtam Suhrab, Raja Somu, Jagan Jeevan, Nurul Haqimin Mohd Salleh, and Rosmaizura Mohd Zain, "The fourth industrial revolution: a catalyst for regional development in Malaysian seaport sector." *Australian Journal of Maritime & Ocean Affairs* 15, no. 3 (2023): 284-295

7 Jeevan, Jagan, Mahendran Selvaduray, Nurul Haqimin Mohd Salleh, Abdul Hafaz Ngah, and Suhaiza Zailani. "Evolution of Industrial Revolution 4.0 in seaport system: An interpretation from a bibliometric analysis." *Australian Journal of Maritime & Ocean Affairs* 14, no. 4 (2022): 229-250

8 Salleh, Nurul Haqimin Mohd, Mahendrran Selvaduray, Jagan Jeevan, Abdul Hafaz Ngah, and Suhaiza Hanim Mohamad Zailani, "Prioritizing the critical sustainable factors for the industrial revolution 4.0 in Malaysian seaports sector by using analytic hierarchy process." in AIP *Conference Proceedings*, vol. 2484, no. 1, p. 030005. AIP Publishing LLC, 2023

9 Chiu, Rong-Her, Le-Hui Lin, and Shih-Chan Ting. "Evaluation of green port factors and performance: a fuzzy AHP analysis," *Mathematical problems in engineering* 2014 (2014)

10 Dawes, John. "Do data characteristics change according to the number of scale points used? An experiment using 5-point, 7-point and 10-point scales," *International journal of market research* 50, no. 1 (2008): 61-104

11 Mohamad, Effendi, Lukman Sukarma, Nor Akramin Mohamad, Mohd Rizal Salleh, Muhamad Arfauz A. Rahman, Azrul Azwan Abdul Rahman, and Mohd Amri Sulaiman. "Review on implementation of Industry 4.0 globally and preparing Malaysia for fourth industrial revolution," in *The Proceedings of Design & Systems Conference* 2018.28, p. 2203. The Japan Society of Mechanical Engineers, 2018

12 Ancarani, Alessandro, Carmela Di Mauro, Hervé Legenvre, and Marco Stefano Cardella. "Internet of things adoption: a typology of projects." *International Journal of Operations & Production Management* 40, no. 6 (2020): 849-872

13 He, Kaifei, and Man Jin. "Cyber-Physical systems for maintenance in Industry 4.0," (2016)

14 Kiel, Daniel, Julian M. Müller, Christian Arnold, and Kai-Ingo Voigt. "Sustainable industrial value creation: Benefits and challenges of industry 4.0," *International journal of innovation management* 21, no. 08 (2017): 1740015

15 Zhong, IEEE

16 Muhammad, Bilal, Ambuj Kumar, Ernestina Cianca, and Peter Lindgren. "Improving port operations through the application of robotics and automation within the framework of shipping 4.0," *in 2018 21st International Symposium on Wireless Personal Multimedia Communications* (WPMC), pp. 387-392. IEEE, 2018

17 Selvaduray, Mahendrran, Yapa Mahinda Bandara, Rosmaizura Mohd Zain, Ainon Ramli, and Mohd Zaimmudin Mohd Zain. "Bibliometric analysis of maritime tourism research." *Australian Journal of Maritime & Ocean Affairs* (2022): 1-27

18 Stani , Venesa, Marko Hadjina, Nikša Fafandjel, and Tin Matulja. "Toward shipbuilding 4.0-an industry 4.0 changing the face of the shipbuilding industry." *Brodogradnja: Teorija i praksa brodogradnje i pomorske tehnike* 69, no. 3 (2018): 111-128

19 Gimenez, Cristina, Vicenta Sierra, and Juan Rodon. "Sustainable operations: Their impact on the triple bottom line." *International journal of production economics* 140, no. 1 (2012): 149-159

20 Kang, Dalwon, and Sihyun Kim. "Conceptual model development of sustainability practices: The case of port operations for collaboration and governance." *Sustainability* 9, no. 12 (2017): 2333

21 Sedat, Ba tu , Gamze Arabelen, Ceren Altunta Vural, and Durmu Ali Deveci. "A value chain analysis of a seaport from the perspective of Industry 4.0," *International Journal of Shipping and Transport Logistics* 12, no. 4 (2020): 367-397

22 Bakkari, M., & Khatory, A. (2017, April). Industry 4.0: strategy for more sustainable industrial development in SMEs. In Proceedings of the IEOM 7th International Conference on Industrial Engineering and Operations Management, Rabat, Morocco (pp. 11-13)

23 Yunus, Riduan, and Jay Yang. "Improving ecological performance of industrialized building systems in Malaysia," *Construction Management and Economics* 32, no. 1-2 (2014): 183-195

24 Gouvea, Raul, Dimitri Kapelianis, and Sul Kassicieh. "Assessing the nexus of sustainability and information & communications technology," *Technological Forecasting and Social Change* 130 (2018): 39-44

25 Mrugalska, Beata, and Magdalena K. Wyrwicka, "Towards lean production in industry 4.0." *Procedia engineering* 182 (2017): 466-473

26 Hareide, Odd Sveinung, Øyvind Jøsok, Mass Soldal Lund, Runar Ostnes, and Kirsi Helkala. "Enhancing navigator competence by demonstrating maritime cyber security." *The Journal of Navigation* 71, no. 5 (2018): 1025-1039

27 Chiu, Rong-Her, Le-Hui Lin, and Shih-Chan Ting. "Evaluation of green port factors and performance: a fuzzy AHP analysis." *Mathematical problems in engineering* 2014 (2014)

28 Kuhl, Marcos Roberto, João Carlos Da Cunha, Marlete Beatriz Maçaneiro, and Sieglinde Kindl Cunha. "Relationship between innovation and sustainable performance." *International Journal of Innovation Management* 20, no. 06 (2016): 1650047

29 Barquet, Ana Paula, Johannes Seidel, Günther Seliger, and Holger Kohl. "Sustainability factors for PSS business models." *Procedia Cirp* 47 (2016): 436-441

30 Tran, Thi Minh Trang, Kum Fai Yuen, Kevin X. Li, Gökcay Balci, and Fei Ma. "A theory-driven identification and ranking of the critical success factors of sustainable shipping management." *Journal of Cleaner Production* 243 (2020): 118401

31 Jeevan, Jagan, Mohamand Rosni Othman, Nurul Haqimin Mohd Salleh, Anuar Abu Bakar, Noor Apandi Osnin, Mahendrran Selvaduray, and Noorlee Boonadir. "Interpretations of Maritime Experts on the Sustainability of Maritime Education: Reducing the Lacuna of Amalgamation Between Maritime Education and Industries." In Design in Maritime Engineering: Contributions from the ICMAT 2021, pp. 339-357. Cham: Springer International Publishing, 2022

32 Jayashree, Sreenivasan, Chinnasamy Agamudai Nambi Malarvizhi, and Mohammad Nurul Hassan Reza, "The Impact of Organizational Readiness on IR 4.0 and Sustainability-A Conceptual Framework for SMEs in Malaysia," (2019)

33 Jeevan, Jagan, Rosni Othman, Madzli Harun, Mahendrran Selvaduray, and Rosmaizura Mohd Zain. "Incorporation of Dry Ports into the National Transport Policy: A Proposal for International Trade Acceleration," *Transactions on Maritime Science* 12, no. 1 (2023)

34 Hermann, M., Pentek, T., & Otto, B. (2016). "Design principles for industrie 4.0 scenarios—paper presented at the 49th Hawaii international conference on system sciences". *IEEE Computer Society*, 10

35 Vaidya, Saurabh, Prashant Ambad, and Santosh Bhosle, "Industry 4.0–a glimpse." *Procedia manufacturing* 20 (2018): 233-238

36 Singh, Gurinder, and Inderpreet Singh Ahuja. "Just-in-time manufacturing: literature review and directions," *International Journal of Business Continuity and Risk Management* 3, no. 1 (2012): 57-98

37 Salleh, Nurul Haqimin Mohd Salleh, Rudiah Md Hanafiah, Abdul Hafaz Ngah, Jagan Jeevan, Lazim Abdullah. A Framework Proposal for Evaluating the Organizational Reliability and Capability of a Liner Shipping Operator in a Fuzzy Context, *Special Issue*, 8(6S3), pp.327–341, https://doi.org/10.35940/ijeat.f1053.0986s319

38 Basant, Rakesh. "Intellectual property and innovation: Changing perspectives in the Indian IT industry." *Vikalpa* 29, no. 4 (2004): 69-82

39 Waters, Donald. Supply chain risk management: vulnerability and resilience in logistics. *Kogan Page Publishers*, 2011

40 Burskyte, Vilma, Olga Belous, and Zaneta Stasiskiene. “Sustainable development of deep-water seaport: The case of Lithuania.” *Environmental Science and Pollution Research* 18 (2011): 716-726

41 Bonilla, Silvia H., Helton RO Silva, Marcia Terra da Silva, Rodrigo Franco Gonçalves, and José B. Sacomano. “Industry 4.0 and sustainability implications: A scenario-based analysis of the impacts and challenges.” *Sustainability* 10, no. 10 (2018): 3740

42 Haddud, Abubaker, Arthur DeSouza, Anshuman Khare, and Huei Lee. “Examining potential benefits and challenges associated with the Internet of Things integration in supply chains.” *Journal of Manufacturing Technology Management* (2017)

43 Salleh, Nurul Haqimin Mohd, Nur Ain Solehah Abd Rasidi, and Jagan Jeevan. “Lean, agile, resilience and green (LARG) paradigm in supply chain operations: a trial in a seaport system.” *Australian Journal of Maritime & Ocean Affairs* 12, no. 4 (2020): 200-216

44 Salleh, Nurul Haqimin Mohd, Ramin Riahi, Zaili Yang, and Jin Wang. “Predicting a containership’s arrival punctuality in liner operations by using a fuzzy rule-based bayesian network (frbbn).” *The Asian Journal of Shipping and Logistics* 33, no. 2 (2017): 95-104

45 Bhattacharjea, Aditya. “Labour market regulation and industrial performance in India: A critical review of the empirical evidence.” *Indian Journal of Labour Economics* 49, no. 2 (2006): 211-232

46 Jeevan, J., M. R. Othman, A. H. Saharuddin, G. K. Park, and T. M. H. Do. “An evolution of a nexus between Malaysian seaport centric logistic and Industrial Revolution 4.0: Current status and future strategies.” *International Journal of e-Navigation and Maritime Economy* 10 (2018): 1-15

47 Schroeder, Andreas, and Ali Ziaee Bigdeli. “Capturing the Benefits of Digitalization and Service Innovation: A Business Network Perspective,” in *Academy of Management Proceedings*, vol. 2018, no. 1. 2018

48 Rasidi, Nur Ain Solehah ABD, Nurul Haqimin MOHD SALLEH, and Jagan JEEVAN. “Compatibility Analysis of New Lean, Agile, Resilience and Green (LARG) Paradigm for Enhancing Seaport Supply Chain Practices .” (2017)

49 Yunus, Riduan, and Jay Yang. “Critical sustainability factors in industrialised building systems,” *Construction Innovation* 12, no. 4 (2012): 447-463

50 Sengar, Vikas Singh, Chandra Prakash Garg, and T. Bangar Raju. “Assessment of sustainable initiatives in Indian ports using AHP framework,” *International Journal of Business Excellence* 16, no. 1 (2018): 110-126

51 Ha, Min Ho, Zaili Yang, and Man Wook Heo. “A new hybrid decision making framework for prioritising port performance improvement strategies,” *The Asian Journal of Shipping and Logistics* 33, no. 3 (2017): 105-116

52 Lee, Jay, Hung-An Kao, and Shanhu Yang. "Service innovation and smart analytics for industry 4.0 and big data environment." *Procedia cirp* 16 (2014): 3-8

53 Manavalan, Ethirajan, and Kandasamy Jayakrishna. "A review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirements." *Computers & Industrial Engineering* 127 (2019): 925-953

54 Ngah, Abdul Hafaz, Ramayah Thurasamy, Nurul Haqimin Mohd Salleh, Jagan Jeevan, Rudiah Md Hanafiah, and Bilal Eneizan. "Halal transportation adoption among food manufacturers in Malaysia: the moderated model of technology, organization and environment (TOE) framework." *Journal of Islamic Marketing* 13, no. 12 (2022): 2563-2581

55 Lawer, Eric Tamatey, Johannes Herbeck, and Michael Flitner. "Selective adoption: How port authorities in Europe and West Africa Engage with the globalizing 'Green Port'idea." *Sustainability* 11, no. 18 (2019): 5119

56 Eshuis, Jasper, Erik Braun, and Erik Hans Klijn. "Place marketing as governance strategy: An assessment of obstacles in place marketing and their effects on attracting target groups." *Public administration review* 73, no. 3 (2013): 507-516

57 McMurray, Isabella, Charlotte Brownlow, and Perry R. Hinton. *SPSS explained*. (Routledge, 2014)

58 Ong, Mohd Hanafi Azman, and Fadilah Puteh. "Quantitative data analysis: Choosing between SPSS, PLS, and AMOS in social science research." *International Interdisciplinary Journal of Scientific Research* 3, no. 1 (2017): 14-25

59 Teddlie, Charles, and Fen Yu. "Mixed methods sampling: A typology with examples." *Journal of mixed methods research* 1, no. 1 (2007): 77-100

Climate Change and Environmental Issues

The Panama Canal's Battle Against Climate Change

Cdr Y Hemanth Kumar

Sweltering under an intense heat wave exacerbated by the *El Niño* weather system, India's capital city New Delhi is feeling the effects [1] of a global climate phenomenon that extends far beyond India's borders. This same *El Niño* is contributing to an unprecedented drought in Panama, leading to historically low water levels in the Panama Canal - a vital artery for global trade that facilitates the movement of $270 billion[2] worth of merchandise annually. The canal, crucial for the seamless passage of vessels worldwide, is now grappling with a 20-year decline in freshwater levels. The resulting water scarcity has forced the Panama Canal Authority to impose reduced draught limits and daily vessel passage restrictions, leading to longer wait times, higher tolls, and a freshwater surcharge increase surpassing 10 percent. These measures are causing shipping companies, especially those operating bulk carriers and tankers, to resort to auctions for canal slots, significantly escalating passage charges and forcing some to consider alternative routes, thereby potentially disrupting global trade dynamics. The ramifications of the Panama Canal's water crisis ripple across the globe, including India. India's trade, heavily reliant on efficient international shipping routes, faces potential delays and increased costs. The diversion of bulk carriers and tankers to alternative routes could lead to a significant rise in shipping costs for Indian importers and exporters operating on this route.

To alleviate the canal's water scarcity, the Panama Canal Authority has proposed a US$2 billion initiative to redirect additional rivers into the canal. This initiative underscores the urgent need for a delicate balance between water resource management, environmental sustainability, and sustained economic growth. As New Delhi battles the severe heat wave, it serves as a stark reminder of the interconnectedness of global climate events and their far-reaching impacts. The *El Niño* induced drought in Panama and its cascading effects on global trade highlight the critical importance of addressing climate change and managing our natural resources wisely to ensure economic stability and growth.

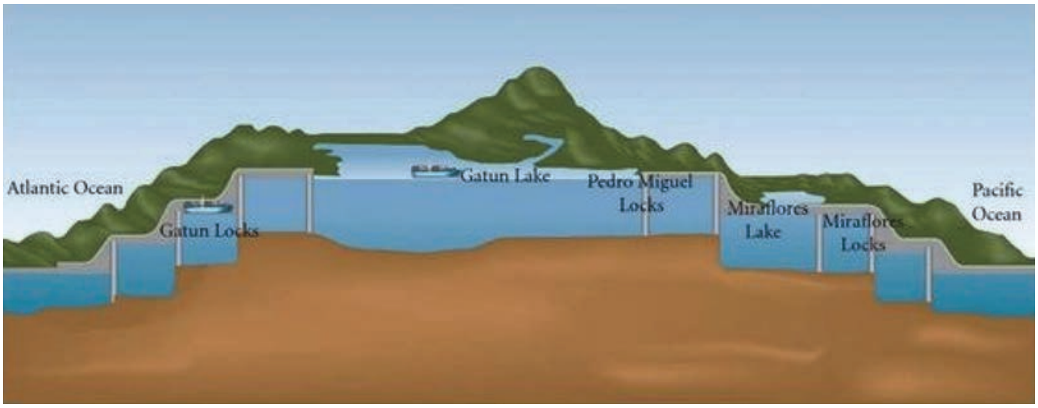
In recent months, the Panama Canal, which handles approximately 40 per cent[3] of worldwide vessel traffic, has encountered an unprecedented challenge of low water levels created by severe drought conditions, intensified by *El Niño*. This has had far-reaching effects on industries, shipping, and global commerce. The initial phase of the crisis saw a reduction in booking slots, restricting the number of vessels permitted to traverse the Panama Canal. Draft limitations were imposed, mandating that vessels passing through the canal carry less weight, thereby reducing their overall cargo-carrying capacity. Simultaneously, booking slots continued to shrink, compounding the challenges faced by shipping companies and disrupting supply chains. As a result, by the end of August 2023, the Panama Canal faced a backlog of around 200 ships, some stalled for more than 20 days[4], signaling a crisis in this historic waterway.

Panama Canal: Dwindling Freshwater supply

Since its inauguration in 1914, the Panama Canal has played a crucial role in global shipping by connecting the Atlantic and Pacific Oceans, reducing travel time between the two by approximately five days. This strategic waterway, managed by the Panama Canal Authority, handles around 55 per cent of all container cargo[5] destined for the United States from Asia, with approximately 13,000 transits[6] occurring annually under normal circumstances. The canal's unique system of locks elevates ships to about 85 feet above sea level before lowering them to the opposite end (Figure 1). However, each transit results in the loss of up to 50 million gallons[7] of fresh water to the sea, drawn from freshwater lakes sustained by rainfall, which is enough to fill as many as 76 Olympic-sized swimming pools[8].

Panama, ranked as the world's 5th rainiest country in the world, faces challenges due to a 20-year decline in precipitation. Despite being rich in rainfall, Panama normally experiences a dry season from December to April, with the rainy season

Figure 1: Schematic - Panama Canal being fed from freshwater

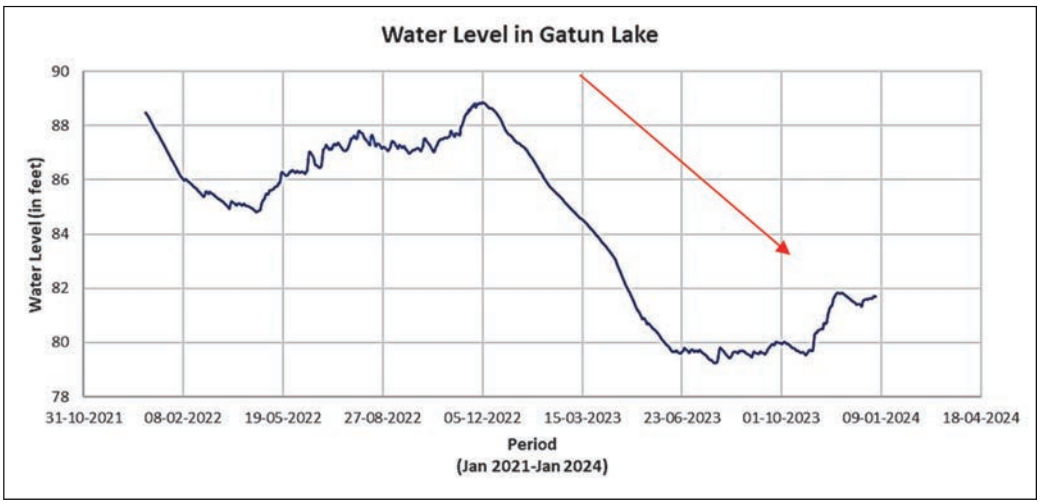


Courtesy: Hindawi Publishing Corporation[9]

typically starting in May and ending in November. However, during *El Niño* year, the onset of rain is delayed, prolonging the dry season. In particular, the *El Niño* phenomenon has adversely impacted *Gatun Lake* which is dependent on rainfall.

As per reports[10], while the water body usually receives 7hm³ (cubic hectometres) daily from rainfall and river flow, combined outflows from canal operations, evaporation, human consumption, and industry totalled 10 hm³, resulting in a

Figure 2: Drastic reduction in Water Level in Gatun Lake



Courtesy: Canal De Panama[12]

daily deficit of 3 hm^3. In a typical rainfall year, the daily water inflow averages 15 hm^3. For the year 2023, water consumption exceeded *Gatun* Lake's intake, forcing the canal to rely on water accumulated during the previous year's rainy season and transfers from other lakes.

The daily deficit of 3 hm^3 is equivalent to the volume of water in 1,200 Olympic-sized swimming pools[11], leading to a record seven-foot drop in the Gatun reservoir's level (Figure 2) during the current rainy season.

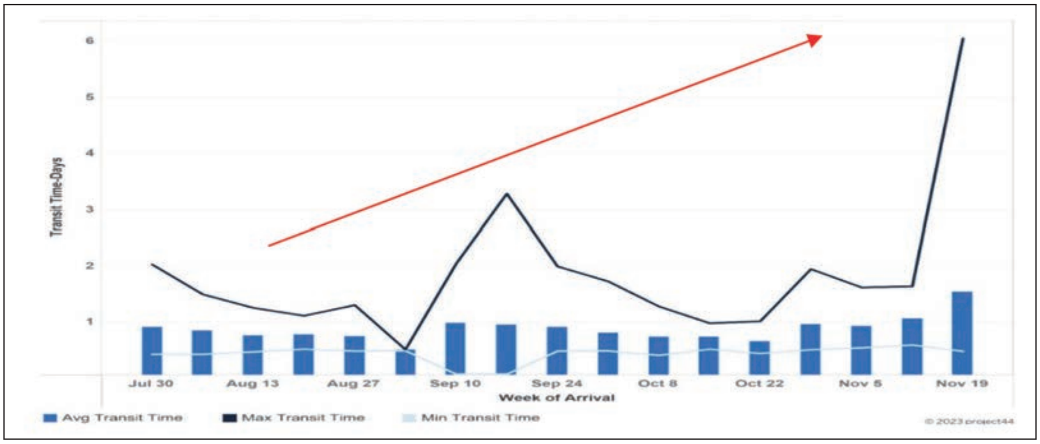
Navigating Drought: Draught limits and Cargo reductions

Between March-May 2023, the maximum authorised draught of a ship in the Panama Canal was reduced from 14.78m[13] to 13.41m[14]. For a container vessel, on average, every foot of draught represents about 300 to 350 containers[15]. By 01 Aug 2023, the daily transit capacity was reduced to an average of 32 vessels per day[16] and as of 01 Nov 2023, the daily slot booking was reduced to 25 per day[17]. This translates to an approximate 30 per cent[18] reduction in the cargo-carrying capacity of container vessels. The trend is likely to continue into 2024. This reduction in the number of vessels translates to an approximate 40-50 per cent[19] reduction in container volume which is in addition to the volume reduction due to draught restriction on every vessel. When analysing transit times, it is seen that by mid-November 2023, there was a 250 per cent[20] increase in the maximum transit time increasing from approximately 1.7 days to 6 days in 2023[21] (Figure 3). This has increased to 22 days as of 20 Jan 24 (Figure 4)[22], whilst anchorage time awaiting passage through the canal has increased between 100-143 per cent[23], which is leading to vessel congestion near the entrance.

Changes in Shipping Practices

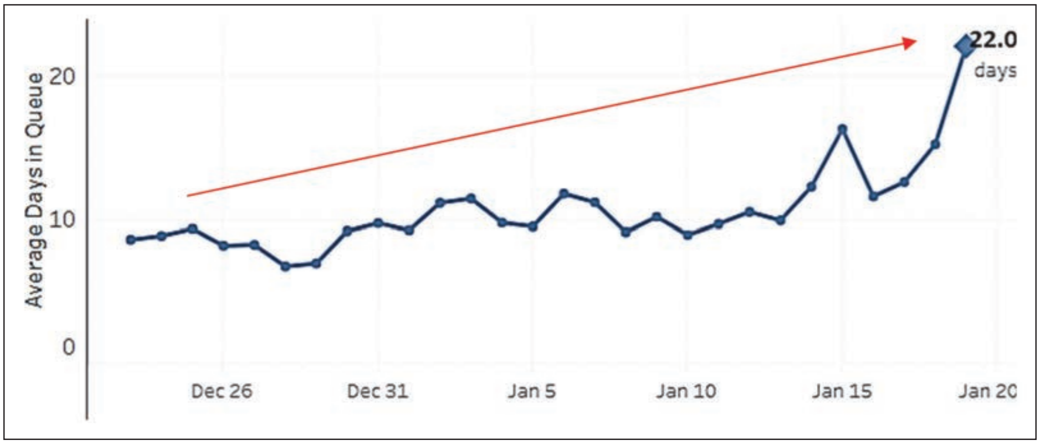
Exacerbating the challenges faced by these vessels, bulk carriers and tankers that primarily transport goods from the US East Coast to Asian destinations are redirecting traffic from the Panama-transpacific route to either the Suez Canal or around the

Figure 3: Increase in transit times of Panama Canal [24]



Courtesy: Project 44[24]

Figure 4: Increase in transit queue time to 22 days in the Panama Canal as of 20 Jan 2024[25]

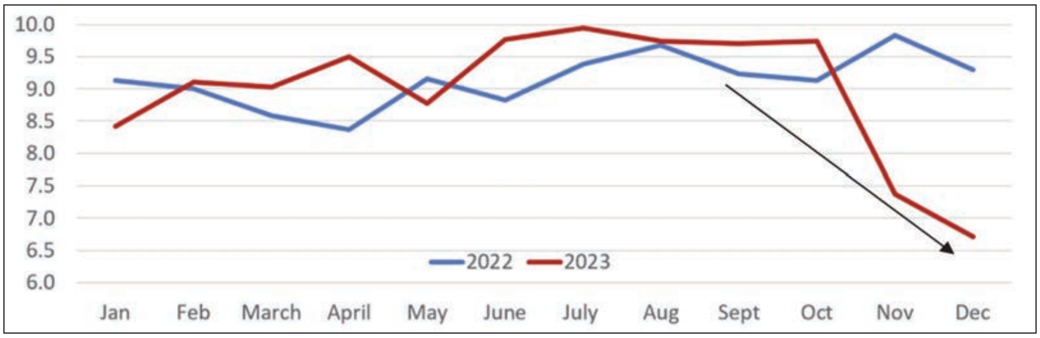


Courtesy: Canal De Panama

Cape of Good Hope. This rerouting increases transit times by two weeks[26]. Delays for unreserved bookings have surged by approximately 280 per cent since June 2023[27], particularly affecting Dry bulk and LNG/LPG carriers[28].

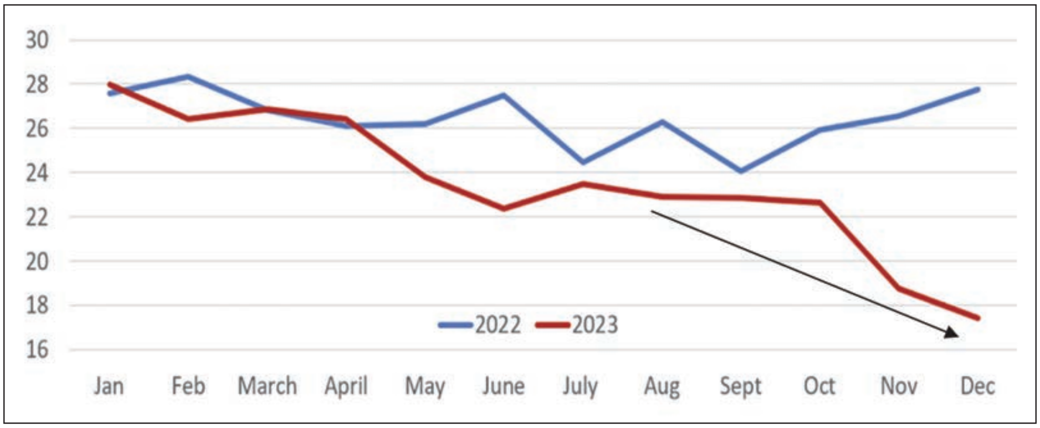
Recent reports indicate that the limited slot bookings available are often pre-booked by container lines operating on fixed routes[29]. Consequently, these vessels must sail with reduced loads from their port of origin and seek alternative destinations

Figure 5: Decrease in Average daily transits through Neopanamax locks



Courtesy: Freightwaves[30]

Figure 6: Decrease in Average daily transits through Panamax locks

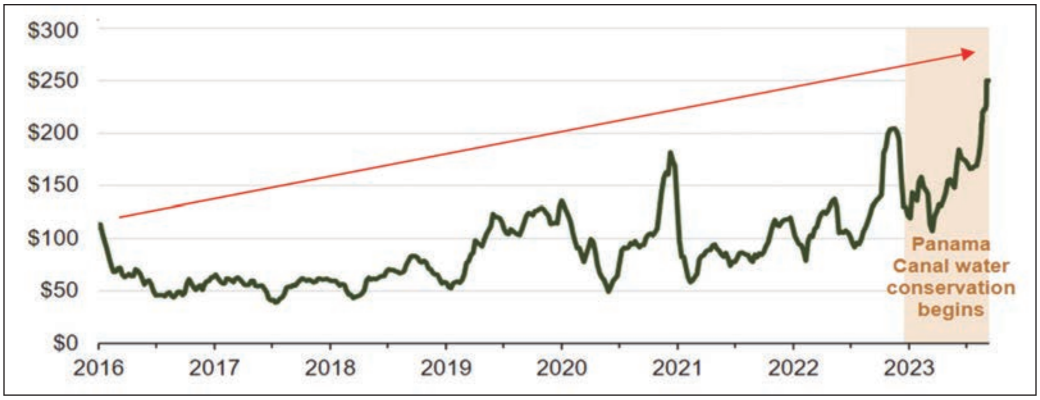


Courtesy: Freightwaves[31]

to augment their cargo after navigating the canal. As a result, the average daily transits through Panamax and Neopanamax dropped by 4.3 per cent and 5.9 per cent (Figure 5 & Figure 6) respectively, relative to Nov 23.

Another approach arising from this crisis involves transferring cargo onto trains[32]. Containers are unloaded from ships on one side of the canal, transported by rail, and reloaded onto vessels before they resume their journey[33]. However, this method cannot be applied to bulk carriers due to the nature of their cargo. In response to the limited cargo capacity offered to customers, major players like *Maersk*, the world's second-largest cargo shipping carrier in terms of capacity, are deploying additional vessels[34] to compensate for cargo shortages and reduced water draught.

Figure 6: Escalation in Shipping Rates for Gas Carriers Panama



Courtesy: BIC Magazine [38]

Financial impact

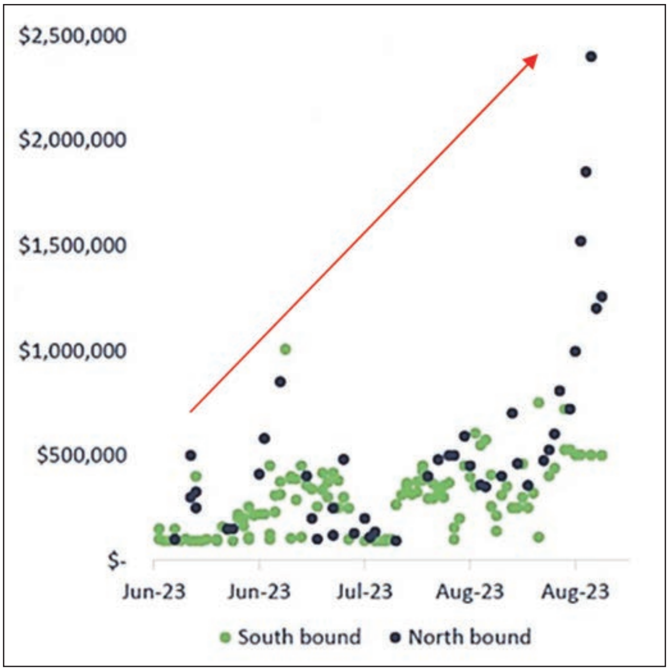
Container vessels which now pay a transit fee of around $400,000[35] to cross the canal are also required with an additional freshwater surcharge of up to 10 per cent[36] due to lower water levels. As a result, shipping companies are charging customers an extra US$600 per container [37], impacting the cost-effectiveness of using the canal. Bulk carriers, owing to scarcity of slots are facing auctions where they have to bid for the limited time slots available, thereby increasing transit costs.

Global Trade Implications

With delays increasing, some bulk carriers are seeking alternate routes, potentially diverting away from the Panama Canal. According to recent findings[40], the situation is anticipated to have significant repercussions for both Southern hemisphere exporters and Northern hemisphere importers. This will affect diverse industries, encompassing Brazilian meat, Chilean wines, and Ecuadorian bananas, among others, which routinely traverse the canal for global trade. Essential commodities such as copper from Chile and natural gas from the US. Gulf Coast also rely on the waterway for transit.

The Panama Canal serves as a swift and cost-effective route for transporting grains and various agricultural commodities from the port of New Orleans to China.

Figure 7: Escalation in Auction Price of Spot Booking for Neo Panamax slot



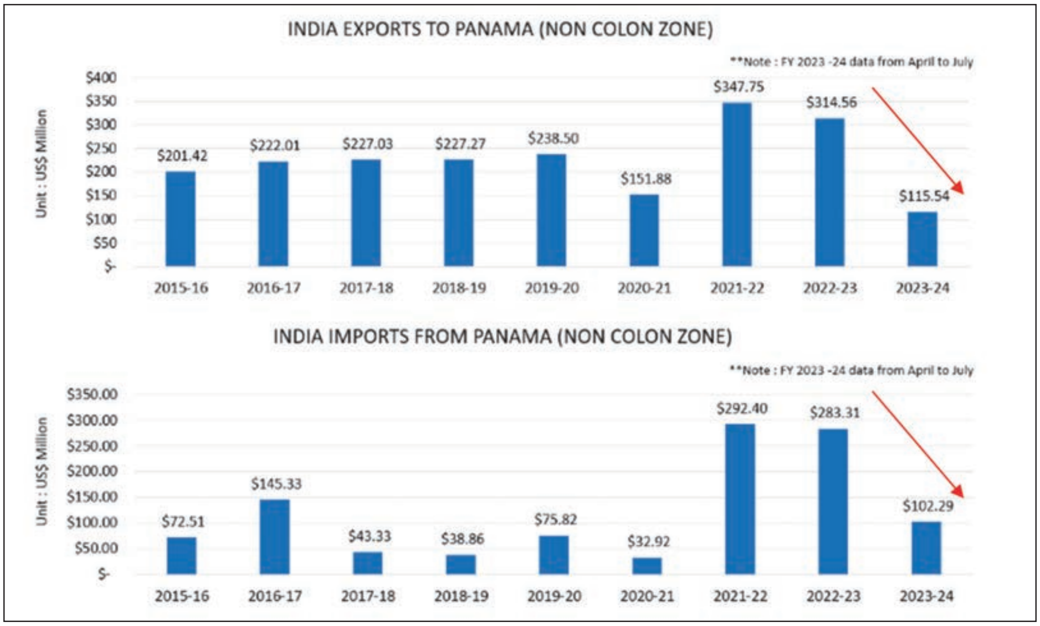
Courtesy: Freightwaves[39]

Since approximately 73 per cent[41] of the canal's traffic involves shipments either destined for or originating from the United States, which has significant implications for the country.

Impact on India

India's trade relationship with Panama in 2022-23 amounted to a total of US$ 597.91 million[42], with exports to Panama at US$ 314.56 million[43] and imports from Panama at US$ 283.35 million[44]. The main items exported from India to Panama include minerals, apparel and textiles, pharmaceuticals, miscellaneous manufactured articles, man-made fibers and filaments, electrical and electronic equipment, soap and washing preparations, and medical/surgical instruments and accessories. On the other hand, India's imports from Panama consist of iron and steel, teak and other wood pulp, aluminium and its articles, mineral fuels, oils and waxes, mineral products, and hides and skins. This robust trade relationship is mutually beneficial, with both nations relying on the seamless transit of goods across crucial maritime routes. However, the recent severe drought affecting the Panama Canal has significantly disrupted this vital trade route. With more than 50% decrease[45] in shipping activity due to water scarcity, vessels are forced to divert to alternative routes like the Suez Canal, adding an additional six days to their transit time. This shift has profound economic implications for India. Increased transit times and the necessity of longer routes result in higher shipping costs, contributing to a general rise in global freight rates. This directly impacts the cost and efficiency of India's exports to Panama and other destinations, making Indian goods less competitive due to higher logistical expenses. Similarly, the import of essential commodities from Panama becomes more expensive and delayed, affecting industries that rely on these materials. The prolonged bottlenecks at the Panama Canal necessitate strategic adjustments in India's trade and logistics policies to mitigate these economic challenges and ensure the resilience of its trade infrastructure.

Figure 8: Reduction in EXIM trade between India and Panama due to Drought



Courtesy: Research and Information System for Developing Countries[46]

Future Outlook

To deal with the situation, the Panama Canal Authority has instituted a $2 billion[47] initiative, which aims to redirect four additional rivers (over and above the existing three rivers) to feed the canal. This endeavour has its own set of challenges, such as high costs, protracted timelines, and adverse ecological impact in the region due to additional infrastructure. The proposed initiative is also likely to stretch the region's already limited water resources and this would be a significant challenge, since the region houses over 2 million people and also hosts a rich rainforest ecosystem[48]. Competing demands between ship transits, human consumption and environmental requirements could possibly flare tensions, leading to unrest and even conflict.

Beyond Panama Canal

The utilisation of freshwater in the Panama Canal, a vital waterway connecting the Atlantic and Pacific Oceans, underscores a fundamental paradox in our approach to problem-solving. While the engineering marvel of the canal has undeniably enhanced global trade and economic efficiency, its sole reliance on scarce resources freshwater prompts a deeper reflection on the interconnectedness of technological progress and environmental stewardship. In an era of climate crisis and water scarcity, the use of freshwater for maritime transit challenges conventional wisdom and raises questions about economic solutions that may not have adequately addressed broader ecological and ethical concerns. Overall, the problem extends beyond the confines of the Panama Canal alone and reflects a larger tension between the development and utilisation of finite resources. It presents an opportunity to reconsider priorities and adopt a more holistic perspective that transcends immediate gains in favour of long-term sustainability.

The Sustainable Development Goals identified by the UN are an example of conscientious progress and offer insight into more responsible economic development. Speaking at the COP 26 in Glasgow on 1st of November 2021, the Indian Prime Minister, Shri Narendra Modi, articulated the concept of 'Lifestyle for the Environment (LiFE), calling upon the global community of individuals and institutions to drive LiFE as an international mass movement towards, "Mindful and Deliberate Utilization, instead of Mindless and Destructive Consumption" to protect and preserve the environment.[49] LiFE puts individual and collective duty on everyone to live a life that is in tune with Earth and does not harm it. Those who practice such a lifestyle are recognised as Pro Planet People under LiFE. His statement is exemplified by India's approach to human-centric progress, captured in the two words "*Vasudhaiva Kutumbakam*" – The world is one family.

Disclaimer: Views expressed are of the author and do not necessarily reflect the views of the Government of India.

06 August 2024

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ENDNOTES

1 "Indian Capital Swelters through Heatwave as Temperature Reportedly Passes 52C in Delhi," *ABC News*, 30 May, 2024,https://www.abc.net.au/news/2024-05-30/india-delhi-heatwave-records-temperature-climate-change/103911178

2 Lori Ann LaRocco, "U.S. Trade Dominated Panama Canal Traffic. New Restrictions Due to Severe Drought Are Threatening the Future of the Shipping Route," *CNBC*, accessed January 21, 2024, https://www.cnbc.com/2023/06/24/us-trade-dominates-panama-canal-traffic-a-drought-is-threatening-it.html#:~:text=The U.S. is the largest,%24270 billion in cargo annually

3 "Impacts of Increased Restrictions Are Emerging in the Panama Canal," *Project 44*, 2023, https://www.project44.com/blog/the-panama-canals-struggle-with-lower-capacity-extended-transit-times

4 Kamal Sultan, "Huge Backlong of 200 Ships Are Stuck Trying to Enter Panama Canal as They Wait Weeks amid Slowed Traffic Due to Drought: Delays Set to Wipe $ 200m off Profits and Cause Spike in US Grocery and Parcel Prices," *Mail Online*, 2023, https://www.dailymail.co.uk/news/article-12427501/Huge-backlog-200-ships-stuck-trying-enter-

Panama-Canal-wait-WEEKS-amid-slowed-traffic-drought-Delays-set-wipe-200M-profits-cause-spike-grocery-parcel-prices.html

5 “Record Low Rainfall Disrupts Panama Canal Crossings,” *Boston Consulting Group*, accessed January 22, 2023, https://www.bcg.com/publications/2023/record-low-rainfall-disrupts-panama-canal-crossings

6 “Panama Drought and Its Impact on Bulk Shipping,” *Hellinic Shipping News Worldwide*, 2023, https://www.hellenicshippingnews.com/panama-drought-and-its-impact-on-bulk-shipping/#google_vignette

7 Diana Roy, “What’s Causing the Panama Canal Logjam,” *Council on Foreign Relations*, 2023, https://www.cfr.org/in-brief/whats-causing-panama-canal-logjam

8 Diana Roy, “What’s Causing the Panama Canal Logjam,” *Council on Foreign Relations*, 2023, https://www.cfr.org/in-brief/whats-causing-panama-canal-logjam

9 Luis Rabelo et al., “Preliminary Hybrid Modeling of the Panama Canal: Operations and Salinity Diffusion,” *Modelling and Simulation in Engineering* 2012 (2012), https://doi.org/10.1155/2012/806139

10 “Beyond Scarcity : How the Canal Manages the Fresh Water Challenge,” Canal De Panama, 2023, https://pancanal.com/en/how-the-canal-manages-the-fresh-water-challenge/#:~:text=Beyond Scarcity%3A How the Canal Manages the Fresh Water Challenge,-Tags%3A Canal Connection&text=The year 2023 has been,May and ends in November

11 “Beyond Scarcity : How the Canal Manages the Fresh Water Challenge,” Canal De Panama, 2023, https://pancanal.com/en/how-the-canal-manages-the-fresh-water-challenge/#:~:text=Beyond Scarcity%3A How the Canal Manages the Fresh Water Challenge,-Tags%3A Canal Connection&text=The year 2023 has been,May and ends in November

12 Canal De Panama, “Gatun Lake Historical Water Levels,” 2024, https://evtms-rpts.pancanal.com/eng/h2o/index.html

13 Panama Canal Authority, “Advisory to Shipping No A-41-2016,” Pub. L. No. A-20-2021 (2021), https://pancanal.com/wp-content/uploads/2021/04/ADV-20-2021.pdf

14 Panama Canal Authority, “Advisory To Shipping No A-30-2023,” Pub L No A-30-2023 (2023), https://pancanal.com/wp-content/uploads/2023/01/ADV30-2023-Postponement-of-the-Maximum-Authorized-Draft-for-Vessels-Transiting-the-Panama-Canal..pdf

15 Luke Vargas, Drought Strains the Panama Canal and Global Trade (WSJ Podcasts, 2023), https://www.wsj.com/podcasts/whats-news/drought-strains-the-panama-canal-and-global-trade/d735e939-65f2-4d5d-bd4b-9cca52628e83

16 “Drought Conditions Worsen in the Panama Canal,” 2023, Supply Chain Insights, https://supplychaininsights.project44.com/drought-conditions-worsen-in-the-panama-canal/

17 “Impacts of Increased Restrictions Are Emerging in the Panama Canal”

18 “Drought Conditions Worsen in the Panama Canal,” 2023, Supply Chain Insights, https://supplychaininsights.project44.com/drought-conditions-worsen-in-the-panama-canal/

19 Lori Ann Larocco, “Panama Canal Drought Hits New Crisis Level with Nearly Half of Vessel Traffic Targetted for Cuts,” 2023, *CNBC* accessed January 10, 2024, https://www.cnbc.com/2023/11/03/panama-canal-drought-hits-new-crisis-level-amid-severe-el-nino.html

20 “Impacts of Increased Restrictions Are Emerging in the Panama Canal”

21 “Impacts of Increased Restrictions Are Emerging in the Panama Canal”

22 “Vessels Statistics and Transit Backlog in the Panama Canal,” Canal De Panama, 2024, https://apps.pancanal.com/t/TI/views/DashboardColadeEspera/DashboardCola-EN?%3AisGuestRedirectFromVizportal&%3Aembed=y&%3Ahighdpi

23 “Impacts of Increased Restrictions Are Emerging in the Panama Canal.”

24 Jenna Slagle, “Navigating Troubled Waters : The Panama Canal’s Struggle with Lower Capacity, Extended Transit Times, and Anchorage Surges during Drought Conditions,” project 44, 2023, https://www.project44.com/blog/the-panama-canals-struggle-with-lower-capacity-extended-transit-times

25 “Vessels Statistics and Transit Backlog in the Panama Canal,” Canal De Panama, 2024, https://apps.pancanal.com/t/TI/views/DashboardColadeEspera/DashboardCola-EN?%3AisGuestRedirectFromVizportal&%3Aembed=y&%3Ahighdpi

26 Staff, “Drought in the Panama Canal Expected to Postpone Grain Shipments Untile Late 2024,” *The Latin American Post*, 2024, https://latinamericanpost.com/economy-en/drought-in-the-panama-canal-expected-to-postpone-grain-shipments-until-late-2024/

27 Rebecca Cohen, “A Huge Traffic Jam at the Panama Canal Could Take Atleast 10 Months to Clear Up,” *Business Insider*, August 2023, https://www.businessinsider.in/thelife/news/a-huge-traffic-jam-at-the-panama-canal-could-take-at-least-10-months-to-clear-up-and-itll-likely-screw-up-your-holiday-shopping/articleshow/103221664.cms

28 Staff, “Dry Bulk, LNG Bear the Brunt of Panama Canal Transit Woes,” *Zawya Projects*, 30 November 2023, https://www.zawya.com/en/projects/industry/dry-bulk-lng-bear-the-brunt-of-panama-canal-transit-woes-vw5ft9nn

29 “Panama Canal Woes for Dry Bulk,” *Dry Cargo International*, 6 December 2023, https://www.drycargomag.com/panama-canal-woes-for-dry-bulk

30 Greg Miller, “Panama Canal Transits Sink to New Drought-Driven Low in December,” Freightwaves, 19 January 2024, https://www.freightwaves.com/news/panama-canal-transits-sink-to-new-drought-driven-low-in-december

31 Greg Miller, “Panama Canal Transits Sink to New Drought-Driven Low in December,” Freightwaves, 19 January 2024, https://www.freightwaves.com/news/panama-canal-transits-sink-to-new-drought-driven-low-in-december

32 Sreelakshmi HK, “Navigating the Panama Canal Drought Crisis and Its Impact on Global Supply Chains,” *Portcast*, 29 August 2023, https://www.portcast.io/blog/panama-canal-drought-crisis-and-its-impact-on-global-supply-chains

33 Sreelakshmi HK, “Navigating the Panama Canal Drought Crisis and Its Impact on Global Supply Chains,” *Portcast*, 29 August 2023, https://www.portcast.io/blog/panama-canal-drought-crisis-and-its-impact-on-global-supply-chains

34 Maersk, “Maersk North America Market Update - September 2023,” September 2023, https://www.maersk.com/news/articles/2023/09/27/north-america-market-update-september

35 Ruth Liao and Anna Shiryaevskaya Alex Longley, “One Ship in Panama Canal Paid $2.4 Million to Skip the Line,” *Bloomberg News*, 31 August, 2023, https://www.bnnbloomberg.ca/one-ship-in-panama-canal-paid-2-4-million-to-skip-the-line-1.1965721

36 “Modification to Fresh Water Surcharge,” *Gulf Agency Company*, 2023, https://www.gac.com/hot-port-news/modification-to-fresh-water-surcharge

37 “Panama Canal Drought Hits Shippers,” *NAM News Room*, 2023, https://nam.org/panama-canal-drought-hits-shippers-27294/?stream=series-input-stories

38 “Drought at the Panama Canal Delays Enerty Shipments, Increasing Shipping Costs,” *BIC Magazine*, 2023, https://www.bicmagazine.com/departments/lift-transport/drought-at-the-panama-canal-delays-energy-shipments-increasing-shipping-costs/

39 Greg Miller, “Panama Canal Restrictions Are Rerouting LPG Shipping Flows,” *FreightWaves*, 31 August, 2023, http://tinyurl.com/3dx6vvpu

40 “Panama Canal Drought Hits Shippers,” *NAM News Room*, 2023, https://nam.org/panama-canal-drought-hits-shippers-27294/?stream=series-input-stories

41 LaRocco, Lori Ann “U.S. Trade Dominated Panama Canal Traffic New Restrictions Due to Severe Drought Are Threatening the Future of the Shipping Route” *CNBC* Accessed January 21, 2024. https://www.cnbc.com/2023/06/24/us-trade-dominates-panama-canal-traffic-a-drought-is-threatening-it.html#:~:text=The U.S. is the largest,%24270 billion in cargo annually

42 GOI, "India-Panama Bilateral Brief," 2023, https://indianembassypanama.gov.in/public_files/assets/pdf/1_03112023_India-Panama_bilateral_brief.pdf

43 GOI, "India-Panama Bilateral Brief," 2023, https://indianembassypanama.gov.in/public_files/assets/pdf/1_03112023_India-Panama_bilateral_brief.pdf

44 GOI, "India-Panama Bilateral Brief," 2023, https://indianembassypanama.gov.in/public_files/assets/pdf/1_03112023_India-Panama_bilateral_brief.pdf

45 "Maritime Disruptions : Impact on India," RIS, vol. 2023 (Delhi, n.d.),https://ris.org.in/cmec/pdf/Commentary-CMEC.pdf

46 "Maritime Disruptions : Impact on India," RIS, vol 2023 (Delhi, n.d.),https://ris.org.in/cmec/pdf/Commentary-CMEC.pdf

47 Peter Millard and Michael D Mc Donald, "Saving the Panama Canal Will Take Years and Cost Billions, If Its Even Possible," *Bloomberg*, 3 January, 2024, https://www.japantimes.co.jp/news/2024/01/03/world/society/saving-panama-canal-billions/

48 NASA, "Rainforests of Panama," NASA *Earth Observatory*, accessed January 26, 2024, https://earthobservatory.nasa.gov/images/4150/rainforests-of-panama#:~:text=Panama's rainforests are home to,in the Panama Canal watershed

49 https://www.mea.gov.in/Speeches-Statements.htm?dtl/34466/National+Statement+by+Prime+Minister+Shri+Narendra+Modi+at+COP26+Summit+in+Glasgow

Coastal Erosion and Adaptation Measures: An Assessment

Dr Chime Youdon

The Earth boasts an extensive coastal line, where the interface between land and sea dominates its geographic features, distinguished by its expansive aqueous expanse of 361.13 million sq. km, constituting approximately 71% of its total surface area, juxtaposed against the remaining 29% of (148.94 million sq km) terrestrial terrain. The intricate interplay between these elemental domains unfolds along the vast expanse of the coastline, extending over an impressive 1,634,701 kilometres.[1] Remarkably, 84% of the world's nations possess coastlines that interface with open oceans, inland seas, or both, thereby underscoring the pervasive presence and significance of coastal environments on a global scale. These coastal areas are home to over 40% of the world's population and support diverse ecosystems that provide numerous valuable services.[2] Coastal zones have consistently attracted human settlement and activity owing to their abundant amenities, aesthetic appeal, and diverse ecosystem services. Consequently, these areas have witnessed significant population growth and development globally.

Despite their allure, coastlines present dynamic landscapes, posing both intriguing scientific questions and complex management challenges. One such challenge is the escalating issue of coastal erosion, which affects over 75% of the world's coastlines.[3] Coastal erosion, characterised by the gradual loss of land adjacent to water bodies, results in long-term changes that are often challenging to reverse. Defined as *"the rate of change in the position of horizontal displacement of land surfaces, beachfronts, shoreline, or dunes over time,"*[4] coastal erosion is driven by a multitude of interconnected factors. It stems from the relentless forces exerted by waves and currents, although it can also be influenced by mass wasting processes on slopes and land subsidence. Moreover, extreme weather events like coastal storms, surges, heavy rainfall, and flooding frequently trigger significant episodes of coastal erosion.[5] Similarly, *tsunamis* and sea-level rise can exacerbate erosion due to the intensification of waves and currents, which can, during inundation events, reach previously unaffected landforms. Notably, over half of the world's 513 cities with populations exceeding one million in 2015 were located within 100 km of a coastline.[6] Therefore, these changes pose threats to buildings, infrastructure, people, and natural ecosystems — such as salt marshes, mangroves, and coral reefs— that provide valuable ecosystem services and benefits. These services encompass protection from erosion, improvements in water-quality, benefits to recreation and tourism, and fish production. The loss of natural coastal protection features such as dunes, mangroves, and coral, exposes proximate areas to water and wave damage, leading to the destabilisation of land and harm to communities. Furthermore, human activities such as the exploitation of coastal resources, concentration of populations, settlements, socio-economic endeavours, and alterations to sediment dynamics exacerbate coastal erosion and worsen its impact on economic and environmental activities. These impacts include the loss of homes, lives, and livelihoods, human displacement, disruptions to economic sectors, increased water insecurity, and disruptions to key infrastructure like transportation and communication.

This paper aims to highlight prevailing global trends in coastal erosion and examine region-specific protection measures against coastal erosion. Through comparative analyses, it will discuss the effectiveness of existing mitigation measures and identify best practices from a variety of geographical contexts. The paper will, of course, focus on evaluating the potential applicability of these practices in the specific context of India.

Global Coastal Erosion Trends

At the global level, coastal erosion presents a formidable challenge across several regions, each with its own distinct patterns and consequences. From 1984 to 2015, global coastal erosion resulted in the loss of 28,000 square kilometres of permeant land.[7] This net loss of land translates into a reduction of approximately 14,000 square kilometres of surface area available for human settlements and terrestrial ecosystems. Notable regions experiencing substantial changes in coastal dynamics include the Caspian Sea, with an average net cross-shore land-loss of approximately 600 metres. South Asia follows closely with an average land erosion of 158 metres. Additionally, Pacific Asia, Southern America, Eastern Africa, and Western Australia demonstrate average cross-shore erosion exceeding 50 metres.[8] Regions facing extreme levels of coastal erosion, such as the Mekong River delta, the Indus River delta, Small Island Developing States (SIDS), and the Gulf of Mexico, among others, are discussed in the succeeding paragraphs.

Mekong River Delta. From 2016 to 2020, the Mekong River delta in Vietnam experienced significant erosion, totalling 2307 hectares along the coastline.[9] Cai Be faced erosion across 2.1 kilometres, requiring repairs costing approximately 27.7 billion VND (about 1.2 million USD).[10] Additionally, serious erosion threatens the beach of Cua Dai in Quang Nam Province, with an estimated 20% expected to disappear soon.[11]

Indus River Delta. Moving to the Indus River Delta in Pakistan, continuous coastal erosion from 1972 to 2017 has led to significant landward movement and flooding of floodplain areas.[12] This erosion has degraded approximately 42,607 hectares of land due to seawater intrusion, with 31,656 hectares now submerged and 10,951 hectares having been converted into a floodplain.[13] The left bank's floodplain area is approximately 4,208 square kilometres, double that of the right bank (at 2,220 square kilometres), and projections suggest further loss by 2050.[14]

Gulf of Mexico. The Gulf of Mexico region,[15] encompassing states such as Florida, Mississippi, Alabama, Louisiana, and Texas, confronts significant coastal erosion, especially along the Louisiana Gulf coast.[16] Louisiana has experienced the highest rate of wetland loss in the US, accounting for 80% of the nation's coastal wetland loss since 1932, amounting to approximately 1,900 square miles.[17] Despite efforts to combat erosion, wetlands continue to disappear. Natural habitats such as oyster reefs and marshes that protected the Gulf Coast, have been significantly eroded, leaving maritime infrastructure vulnerable to damage.

Yellow River Delta. Similar challenges are observed in China, where significant land loss along coastlines has occurred since the 1990s, with approximately 22% of coastlines eroded. The Yellow River Delta has experienced a notable retreat, with the mangrove coastline in Fangchenggang City eroding by 4 km over the past three decades.[18]

West Coast of South Africa. South Africa's western coast, too, experienced significant erosion, leading to the disappearance of vast portions of beaches that have been submerged into the Atlantic Ocean.[19] Studies show that 95% of the beach has experienced erosion, with an average loss of 38 metres. The most severely eroded area is 6 km north of Ysterfontein, where the shore is 100 m closer to the dunes compared to a century ago. Scientists predict that the ocean could reach the foot of the dune by 2040.[20]

European Union. The European Union has also witnessed the loss of land that has considerable economic and ecological importance. Coastal areas such as De Haan, Sylt, Mamaia, Vecchia Pineta, Giardini Naxos, Sable d'Olonnes, Ghajn Tuffieha, Essex, and Haute-Normandy, are all grappling with erosion. Furthermore, ecologically significant sites such as Scharhoern Island, located along the Elbe estuary, are facing similar challenges.[21]

India and Bangladesh. Bangladesh's coastline also loses 34 square kilometres of land annually, which may increase further with sea level rise.[22] In India, as well, between 1990 and 2018, some 33.6% of India's coastline was vulnerable to erosion, posing severe threats to land, habitats, and the livelihood of fishermen. Essential spaces for activities like boat berthing and fishing operations are at risk due to this coastal retreat.[23]

Small Island Developing States (SIDS). Small Island Developing States (SIDS) face escalating coastal erosion challenges, which are further compounded by extreme weather events such as storm surges, coastal flooding, and sea level rise linked to global warming. Current estimates suggest around 118,000 inhabitants of SIDS are exposed to coastal floods,[24] a number projected to exceed one million by 2070. Sea-level rise has already caused substantial damage to infrastructure and habitats in regions such as the Solomon Islands, where 50% of houses have been lost due to erosion.[25] Projections indicate further sea-level rises by 2050, 2080, and 2100, posing severe consequences for coastal communities of SIDS in terms of erosion.[26]

It is clear that coastal erosion presents a complex and multifaceted challenge globally, requiring coordinated efforts to address its impacts on communities, economies, and ecosystems.

Protection against Coastal Erosion: An Assessment of Adaptation Measures. Adaptation measures in respect of coastal erosion have grown drastically over the past 30 years in parallel with the increasingly obvious impact of erosion across the coastal stretches of the world. In 1990, the IPCC Coastal Zone Management Sub-group report discussed the three main types of adaptation response to coastal climate change, namely, "retreat", "accommodate", and "protect" (with "protection" being further categorised into "hard" and "soft" protection).[27] More recently, additional categories, terminologies, and distinctions have been added such as "no action", "advance", "ecosystem-based adaptation", and "hybrid measures". **Table 1** illustrates some of the various measures undertaken by countries worldwide to combat coastal erosion, categorised into hard structures, soft measures, and ecosystem-based approaches.

Table 1: Protection of Coastal Protection Measures

Country	Hard Structures	Soft Measures	Ecosystem-Based Solutions	Remarks
Vietnam	Concrete sea dykes, revetments	Beach nourishment, dune creation, sandbags	Mangrove reforestation, submerged biomass such as seagrass, macro-algae, coral reefs, etc.	
Pakistan	Migration, seawalls, dikes	Mangrove conservation, Living Indus Initiatives	Mangrove restoration	Forced Retreat
SIDS				
Antigua and Barbuda	Seawalls, revetments, groynes	Reef and mangrove conservation	Mangrove regeneration, coral reef protection	
Bahamas	Seawalls, raised dock height	Beach nourishment, sand dune restoration	Mangrove restoration, coral reef preservation	
Barbados	Revetments, groynes, breakwaters	Beach improvement, dune restoration	Dune stabilization, mangrove rehabilitation	

Belize	Hard structures, beach nourishment	Mangrove restoration, gradual retreat	Mangrove conservation, sedimentation support	
Dominica	Gabion baskets, sea defences	Traditional methods (e.g., coconut-leaf walls)	mangrove protection	Hybrid measures
Guyana	Concrete coastal structures, earth embankments, Dike	sand ridge protection	mangrove planting	
Jamaica	Revetments, groynes	Mangrove regeneration	Beach nourishment, coral replanting	
St Kitts & Nevis	Seawalls, breakwaters	Habitat restoration, no-regret measures	Coastal protection structures, elevated buildings	
St Lucia	Beach replenishment, sea defences	Natural defences (e.g., mangroves, corals)	Mangrove protection, coral reef preservation	
St Vincent & Grenadines	Seawalls	Natural defences (e.g., dunes)	Dune stabilization, reef preservation	
Suriname	Polders, clay dams	Mud bank nourishment, mangrove restoration	Mud bank management, mangrove rehabilitation	
Trinidad & Tobago	Seawalls, breakwaters	Coral reef protection, mangrove conservation	Mangrove rehabilitation, coastal ecosystem protection	
Pacific (15 SIDS)				
Cook Island	Seawalls, raised houses	Coral replanting, Coastal Protection Energy Dissipater (COPED)	Coastal protection measures, reef rehabilitation	
Fiji	Seawalls	Beach nourishment	Mangrove restoration, coral replanting, coastal vegetation planting	
Kiribati	Seawalls	Mangrove replanting	Mangrove rehabilitation, coastal protection	
Marshall Is	Protective structures, temporary beach rock, Elevated homes, raised coral islands	Beach nourishment,	erosion defence, elevated structures	retreat

Micronesia	Seawalls, coral rubble banks	Mangrove rehabilitation	Re-vegetation, elevated homes	
United States	Sea walls, breakwaters, reef balls	Living shorelines, oyster reef restoration, beach nourishment, reef balls	Oyster reef restoration, living shorelines (marshes, reefs), Coastal Resilience 2.0 (oyster reef restoration, ecosystem preservation), Emerald Tutu	Hybrid
Netherlands	Dyke improvements, river widening, multifunctional dykes, retention areas, raise and strengthening dykes	Regarding river widening, lowering floodplain	Multifunctional dykes, wide green dykes, dykes for overtopping Construction of secondary or flood channels, dyke relocation and the use of retention areas	hybrid

Source: Compiled by the Author

Hard Stabilisation

Historically, coastal protection strategies have predominantly involved the fortification of coastal lines through the implementation of physical infrastructure, commonly referred to as "hardening." This approach encompasses the construction of engineered structures such as seawalls, dykes, breakwaters, groynes, and revetments, among others. These structures are fabricated using a diverse range of materials, including boulder revetments, concrete, steel, wooden bulkheads, gabions, and sandbags. These installations are designed to impede the longshore movement of sand and thereby mitigate coastal erosion. Over time, advances in engineering techniques and materials have significantly improved the design and construction of sea walls, rendering them more robust and adaptable to evolving coastal dynamics. Typically, these structures provide the highest level of protection for designated assets and their functional lifetimes can range from 50 to 200 years.[28]

Despite their robustness, however, the construction of sea walls entails considerable costs, necessitating trade-offs and accepting associated side-effects. These rigid defences disrupt natural sediment transport processes, resulting in erosion downstream and the loss of crucial habitats such as beaches and dunes, and destroy habitats, leading to a decline in biodiversity and the marine life dependent on these areas.[29] Many countries, including those bordering the Gulf of Mexico, Vietnam, Sri Lanka, Indonesia, Thailand, and others, have implemented hard defence structures and experienced similar cases of erosion despite these measures.[30] The construction of large-scale coastal defence structures, such as colossal breakwaters and concrete walls, has also been a common method to protect against sea surges.

However, relying solely on these hard structural measures is impractical and can lead to maladaptation. Quite apart from the fact that they require substantial capital investment as well as ongoing maintenance, and can disrupt ecosystems, they may create a false sense of security and encourage development in high-risk areas, thereby exacerbating vulnerability. Unplanned construction of harbours and deep-water ports can worsen erosion and property damage during storm surges. For example, in Pakistan, the unplanned construction of harbours, notably observed in areas like Damb and Pasni, worsens erosion during storm surges, leading to significant property damage. Similarly, development projects for deep-water ports, such as Gwadar East Bay, also contribute to erosion due to wave refraction and construction-related activities.[31]

Soft Measures/ Non-Structural Coastline Protection

In response to the numerous challenges associated with flood and erosion control structures, there has been a notable shift in recent years towards non-structural shore stabilisation techniques, such as beach nourishment, stabilising dunes with fences and vegetation, creating or restoring wetlands, protecting, nourishing, or constructing dunes, etc. "Beach nourishment" has become the most commonly employed response to erosion today, largely due to the negative aspects of hard stabilisation. It involves adding sand to widen beaches, often dredged from adjoining areas or brought in by trucks. Although nourished beaches adapt naturally to the ocean, they require frequent replenishment (every three to four years) and have a limited functional lifespan of between one and ten years. This process has been repeated over 20 times in places like Carolina Beach, North Carolina since its first beach nourishment project.[32] Moreover, beach nourishment has negative impacts on ecosystems and water quality and poses governance challenges, including compliance issues and conflicts with short-term development goals.

Ecosystem-based Approach (EbA)

Soft measures, particularly the ecosystem-based approach, are increasingly gaining popularity across the world. Despite nature being the provider, protector, and regulator since time immemorial, it was not until the Millennium Development Goals, and notably the Millennium Ecosystem Assessment (MA 05) in 2001, that a report on the state of the world's ecosystems finally established a functional link between biodiversity, health, and human well-being.[33] With this recognition, countries across the world began conserving, protecting, and restoring nature and natural ecosystem as a natural defence system against extreme weather events, hazards, and sea level rise. Now EbA appears more regularly than engineered interventions, both in general and across all income groups, especially in developing and least developing countries. A total of 76% of all Nationally Determined Contributions (NDCs) with adaptation components refer to at least one Nature-based Solution (NbS). Of these, over half (53%) have mentioned NbS in the context of three or more distinct types of ecosystems.[34] EbA measures such as coral reefs, mangrove forests, and salt marshes have proven effective in protecting communities and infrastructure from the impacts of climate change while offering numerous co-benefits. Specifically, in Small Island

Figure 1: Photomontage of the Emerald Tutu Project in Boston

Source: MIT News, https://news.mit.edu/2020/emerald-tutu-design-wins-nsf-grant-protect-boston-coastline-0903

Developing States (SIDS), as also in States of Southeast- and South Asia, EbA and NbA strategies are centred upon the leveraging of protective services of coral reef and mangrove systems. Coral reefs serve to dissipate waves and safeguard coastal erosion, whereas mangroves mitigate inland flooding and minimise the impact of strong winds during storms. Many low-income and middle-income countries, including numerous SIDS, have shown a preference for NbS and EbA approaches over engineered interventions, largely due to the lower costs of the former, and the attendant beneficial economic spin-offs in sectors such as tourism and fisheries, and a broader aspiration to transition to a sustainable "blue economy."

Apart from the mangrove forest ecosystem, an innovative solution has been adopted by East Boston, Massachusetts, called the "Emerald Tutu" (the latter word being the name of the stiff, frilly skirt worn by ballerinas). This approach involves a biomass-based coastal protection infrastructure designed for urban areas. As shown in Figure 1, "Emerald Tutus" comprise a floating network of interconnected, anchored massive organic growing modules that effusively dampen wave energy, reduce flooding, storm damage, and erosion along the shore, while simultaneously improving nearshore water quality. These biomass modules are seeded with marsh grass on the surface and harbour a variety of seaweeds below the waterline, increasing mass and frictional surface area providing habitat for diverse marine life. Functioning as a marsh-like structure, the Emerald Tutu dissipates the strength of storm swells in coastal areas and contributes to carbon dioxide and pollutants absorption from the atmosphere and sea. Additionally, it introduces progressive social values in landscaping practices.[35]

"Accommodation" Strategies

"Accommodation" primarily involves the physical raising of buildings or structures to mitigate coastal erosion and flood risks. These are traditionally practised in the Cook Islands, Belize, and Guyana. In Singapore, the focus is on raising the level of reclaimed land and studying long-term protection strategies. Papua New Guinea employs elevated buildings and raised houses to mitigate climate change impacts on high volcanic islands, atolls, raised atolls, cays, coral reefs, and beach forests. The

Marshall Islands has adopted elevated structures, created homes for atolls, and raised coral islands, coral reefs, beaches, beach rocks, and mangroves. The Netherlands' Delta program involves dyke improvements, which raise and/or strengthen dykes, alongside river widening, constructing secondary or flood channels, dyke relocation, and the use of retention areas. However, the implementation of such measures depends heavily upon resource availability and responsibility, whether at the individual or government level. Household-level adaptation depends upon factors such as awareness, perceived responsibility, and available resources. The lifespan of these raised structures hinges upon their design and projected rates of future sea level rise.

"Retreat" from High-risk Areas

As an adaptation strategy, "Retreat" involves strategically and permanently relocating settlements, households, infrastructure, and activities from hazardous locations to safer ones. This measure is commonly adopted in low-lying coastal zones susceptible to sea level rise, storm surges, and inland areas prone to river floods and erosion exacerbated by climate change. Relocating assets away from hazard-prone areas enhances citizen safety and protects goods. Additionally, it creates space for nature to expand, promoting coastal ecosystem restoration. In Europe, successful retreat and relocation measures are evident. For instance, in southwestern France, a road in Sète and Marseillan was moved inland to counter erosion threats, enabling the reconstruction of a larger beach and dune system for enhanced protection.[36] Similarly, in Austria, the government organised a managed process of "retreat" along the Danube River, relocating over 500 households. Compensation covering 80% of the building's value and demolition costs was offered, although vulnerable groups living in less highly valued assets were disadvantaged by this mechanism.[37]

In extreme cases, particularly in SIDS that are challenged by erosion and inundation exacerbated by sea-level rise and extreme weather events such as cyclones and flooding, migration becomes a necessary adaptive measure. However, adaptation by way of human migration is certainly not limited to SIDS. For instance, significant erosion along the Western Indus Delta coastline in Sindh has forced local communities in areas like Shah Bundar, Jati, Khar Chann, Keti Bundar, and Ghorabari, to migrate as a crucial adaptive response.[38] By 2019, approximately 1.2 million people from the coastal areas of the province of Sindh in Pakistan had been displaced by erosion, compelling them to migrate to Karachi.[39] Sea-level rise has led to the loss of nearly 50% of the houses in Nantambu, Solomon Islands, leading residents to migrate.[40] Similarly, in Vietnam, there are 751 eroded areas totalling 976 km in length, with around 20,000 households in the cities of Can Tho and the provinces of Dong Thap, An Giang, Vinh Long and Ca Mau residing in erosion-prone areas, necessitating relocation to safer regions.[41] In response to such challenges, the Maldives has initiated an ambitious project to construct the world's first floating city, offering citizens refuge from losing their lands and homes. Furthermore, Kiribati is implementing a "migrating with dignity" policy, empowering its citizens with the necessary resources and legal framework to relocate to countries like Australia and New Zealand, where they can secure employment opportunities. This proactive approach aims to safeguard the well-being and security of Kiribati's population amidst the imminent threats posed by climate change.

Due to their small size, limited land, and low-lying nature, many SIDS face challenges in adopting "retreat" strategies. For instance, total population removal is considered an option of last resort in places like Papua New Guinea and is reserved for worst-case sea level rise scenarios, as seen in the Marshall Islands. "Managed retreat" is prioritized in Guyana, while Belize considers "gradual retreat" to be a viable long-term option. Grenada, on the other hand, leans towards future abandonment and relocation in cases where the cost of protection work becomes excessive.

"Retreat" measures can be effective when combined with other protective measures, but planned "retreat" is often seen as a potentially irreversible option of last resort. There are serious concerns about the loss of property, cultural values and identity, livelihoods, and territorial integrity associated with retreat measures. Furthermore, the implementation of managed retreat necessitates meticulous coordination across various levels of governance, strict adherence to regulations and land-use plans, and seamless integration into broader spatial planning endeavours. Collaboration amongst stakeholders at local, national, and subnational tiers becomes imperative to navigate the intricate landscape of retreat and ensure the protection of vulnerable communities and ecosystems.

Hybrid Measures

In many developed countries like the United States, "hybrid measures" are being increasingly adopted to provide robust and cost-effective protection against coastal erosion. One successful example is the use of "Living Shorelines". The Mississippi-Alabama Sea Grant (MASGC), for instance, advocates the use of living shorelines as an alternative to bulkheads to address coastal erosion.[42] Bulkheads, while being a traditional option, can have adverse effects such as restricting water access for residents and wildlife, causing erosion of neighbouring properties, and disrupting coastal habitats. On the other hand, "living shorelines" utilise materials such as living plants and oyster shells, along with offshore breakwaters, to combat erosion. MASGC-funded scientists are actively assessing the efficacy of various types of living shorelines and developing tools to help individuals choose the most suitable option for their needs.

In Bangladesh, where annual floods relentlessly erode earthen dykes along the coast, the ECOBAS project (Eco-engineering in Bangladesh) offers a promising solution.[43] Supported by funding from the "Dutch Partners for Water" programme, this innovative initiative focuses on cultivating oysters to counteract the destructive forces of nature. Through a pilot project in southeast Bangladesh, the efficacy of oyster reefs is being tested. These reefs not only bolster sedimentation, safeguarding vulnerable coastlines from erosion, but also double as a sustainable food source. Oysters thrive within the semi-natural reefs formed on concrete block walls, offering a harmonious blend of environmental protection and economic opportunity for the region. "Living shorelines" offer several benefits, including maintaining natural coastal processes and coastal dynamics, creating, or preserving habitats for native aquatic flora and fauna, preserving access for aquatic and terrestrial organisms, maintaining land-to-water access for property owners, and offering cost-effective means of facilitating sediment accumulation. Moreover, "living shorelines" create a natural buffer to mitigate the effects of erosion, trap and retain runoff and pollutants, and contribute to improving water quality.

Arresting Coastal Erosion in India

The Government of India, too, recognises the severity of coastal erosion in its coastal states and territories and has taken several measures to address the issue. Regrettably, however, coastal protection primarily relies upon hard infrastructure such as seawalls, groynes, and breakwaters. These are commonly encountered in states such as West Bengal, Kerala, Karnataka, Mumbai, Tamil Nadu, Goa, and Odisha.[44] More encouraging are the artificial beach nourishment techniques that have been deployed through sand bypass systems at ports such as Visakhapatnam and Paradip. The beach nourishment project initiated by the Puducherry government, utilising 300,000 cubic metres of material, has proven effective in combating erosion.[45] In some regions, hybrid measures combining hard infrastructure with softer materials or techniques have been adopted. For instance, seawalls reinforced with coir bags are used in Kerala, while seawalls reinforced with chains, used in Udwada and Valsad in Gujarat, demonstrate innovative approaches to coastal protection against coastal erosion.[46] Puducherry is employing hybrid measures by combining the construction of artificial reefs using steel structures with beach nourishment.[47]

The Central Water and Power Research Station (CWPRS), Pune, has a major role to play in coastal protection work in India. It is the nodal agency for the country's Coastal Data Bank and conducts training programmes for various State Government Agencies. It has proposed a slew of innovative methods such as flexible gabion, Chain-O-Block (chains), concrete pipes, etc., using locally available material such as sand-filled rubberise coir bags for temporary protection. However, despite the prevalence of hard infrastructure, there have been fairly limited attempts to implement build-with-nature solutions and to adopt ecosystem-based approaches, including mangrove forest restoration or other nature-based solutions.

In extreme cases of coastal erosion-induced displacement, the 15th Finance Commission has allocated 13.51 million US$ (INR 1000 crore) for the resettlement of displaced individuals affected by erosion including losses of land, shelter, and livelihoods, especially for vulnerable coastal communities from 2021 to 2026 under the National Disaster Response Fund (NDRF). Additionally, 202.70 million US$ (INR 1500 crore) has been earmarked for mitigation measures aimed at preventing river and coastal erosion during the same period, under the National Disaster Mitigation Fund (NDMF).[48]

Notably, the Ministry of Environment, Forest & Climate Change (MoEFCC) issued the Coastal Regulation Zone Notification, 2019[49], with the objective of balancing conservation efforts with livelihood security for coastal communities. Given that human developmental activities are amongst the causes of coastal erosion, it is imperative to focus efforts on regulating the coastal zone to achieve a balance between conservation and development. Ironically, however, this notification significantly reduced the No Development Zone (NDZ) from 200 metres to 50 meters from the High Tide Line (HTL) in densely populated areas, allowing construction of resorts, hotels, and tourism facilities right up to the HTL. Such decisions raise concerns, especially considering India's vulnerability to coastal erosion and sea level rise, exacerbated by the high population density within the Low-Elevation Coastal Zone (LECZ).

Mitigating coastal erosion remains a critical challenge under this notification, especially given that previously, the Coastal Regulation Zone 'One' (CRZ)-1 encompassed the most ecologically sensitive areas, including mangroves, coral reefs, sand dunes, and intertidal zones. This designation rendered these areas off-limits for tourism activities and infrastructure development, with exceptions made only for defence, strategic, and rare public utility projects. However, the 2019 notification introduced further categorisation within CRZ-1, permitting *"eco-tourism activities such as mangrove walks, tree huts, nature trails, etc."* in designated eco-sensitive areas, designated them "CRZ-IA".

Unfortunately, these relaxed regulations may inadvertently facilitate the mining of the strategically important mineral sands, a significant contributor to erosion, particularly in coastal areas of Kollam, Alappuzha, and Ernakulam districts of Kerala.[50] Additionally, activities such as sea links, salt harvesting, desalination plants, and roads on stilts are allowed in CRZ-IA. Controversially, land reclamation, which has known significant impacts on coastal ecology, has been sanctioned in intertidal or CRZ-IB areas for ports and sea links. Such increased development in coastal sensitive zones is likely to exacerbate erosion and have adverse impacts on the coastal ecosystem and communities.

Simultaneously, the recent draft amendment of the 2020 Environment Impact Assessment (EIA)[51] has proposed excluding local decision-makers and communities from the decision-making process, thereby disregarding, and marginalising their concerns and traditional environmental knowledge. Indigenous and resource-dependent communities possess invaluable insights into natural disasters and coping mechanisms. Excluding their participation results in the loss of essential knowledge about resources integral to their livelihoods. Such exclusionary policies not only display arrogance and condescension but also perpetuate structural inequalities within the socio-environmental system.

Conclusion

Coastal erosion poses a significant and multifaceted challenge to India's coastal regions, leading to land loss, displacement of communities, and ecological degradation. The prevailing approach to coastal protection relies unduly upon hard infrastructure, which not only disrupts natural processes but also incurs substantial capital and maintenance costs. While soft measures offer temporary relief, they, too, come with their own set of challenges. Ecosystem-based approaches, such as the preservation of mangrove and coral reef ecosystems, hold great promise in mitigating erosion. However, their effectiveness is hindered by limitations such as difficulties in scaling up the measures, as also logistical complexities. Further, the Coastal Regulation Zone Notification of 2019 introduces regulatory concerns regarding the delicate balance between conservation imperatives and developmental aspirations. Success in implementing ecosystem-based adaptations depends on a range of factors, including geographical suitability and community engagement. These challenges are further complicated by regulatory ambiguities, particularly evident in the Environmental Impact Assessment (EIA) 2020 amendments. Addressing these complex challenges requires a comprehensive and nuanced approach that integrates scientific insights, regulatory frameworks, and community participation to effectively safeguard India's coastal areas from the perils of erosion while ensuring sustainable development.

The necessity for India to adopt an integrated approach, combining EbA with hard infrastructure, to mitigate coastal erosion is evident. EbA interventions need to be tailored to local contexts, ensuring resource efficiency, social acceptability, economic viability, and overall benefit. Moreover, exploring alternative strategies, including hybrid approaches, is crucial to identifying the most optimal and cost-effective solutions.

In light of this, adaptation measures for coastal erosion in India necessitate further in-depth research and scrutiny. Tailored solutions, supported by comprehensive research and a deep understanding of coastal dynamics, are essential for ensuring the sustainability of coastal protection efforts. These strategies must demonstrate adaptability and responsiveness to the evolving spectrum of climate risks and the dynamic needs of local communities.

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ENDNOTES

1 Earth Trends, "Coastal and Marine Ecosystem", 16 August 2004 - 02 January 2023, *Internet Archives*, https://web.archive.org/web/20120419075053/http://earthtrends.wri.org/text/coastal-marine/variable-61.html

2 PC Roebeling, CD Coelho, and EM Reis, "Coastal Erosion and Coastal Defense Interventions: A Cost-benefit Analysis", Journal *of Coastal Research,* 64, 1415–1419: (2011), http://www.jstor.org/stable/26482408

3 AT Williams, Nelson Rangel-Buitrago, Enzo Pranzini, Giorgio Anfuso, "The management of coastal erosion", *Ocean and Coastal Management,* 156, 4–20: (2018), https://doi.org/10.1016/j.ocecoaman.2017.03.022

4 George D Haddow, Jane Bullock, and Damon P Coppola, "Natural and Technological Hazards and Risk Assessment" *Introduction to Emergency Management,* 7 (ed), 33-84: (2020), https://doi.org/10.1016/B978-0-12-817139-4.00002-6

See Also: Tanveer Islam and Jeffrey Ryan. "Hazard Identification- Natural Hazards", *Hazard Mitigation in Emergency Management,* 129-170: (2016), https://doi.org/10.1016/B978-0-12-420134-7.00005-9

5 George D Haddow, Jane Bullock, and Damon P Coppola, "Natural and Technological Hazards and Risk Assessment" *Introduction to Emergency Management*, 7 edition, 33-84: (2020), https://doi.org/10.1016/B978-0-12-817139-4.00002-6

6 Theo Notteboom, Athanasios Pallis and Jean-Paul Rodrigue, *Port Economics, Management and Policy*, New York: Routledge (2022), https://porteconomicsmanagement.org/pemp/contents/part7/port-city-relationships/worlds-largest-coastal-cities/

7 Lorenzo Mentaschi, Michael I Vousdoukas, *et al.* "Global long-term observations of coastal erosion and accretion", *Science Reports,* 8, 12876, (2018), https://doi.org/10.1038/s41598-018-30904-w

8 Lorenzo Mentaschi, Michael I Vousdoukas, *et al.* "Global long-term observations of coastal erosion and accretion", *Science Reports,* 8, 12876, (2018), https://doi.org/10.1038/s41598-018-30904-w

9 Hanh TH Pham and Long Ta Bui, "Mechanism of Erosion Zone Formation based on Hydrodynamic Factor Analysis in the Mekong Delta Coast, Vietnam", *Environmental Technology and Innovation,* 30, 103094 (2023), https.//doi.org/10.1016/j.eti.2023.103094

10 Vietnamnet Global, "Mekong Delta Tightens Measures to Fight Erosion", 31 July 2022, *Vietnam Net Global*, https://vietnamnet.vn/en/mekong-delta-tightens-measures-to-fight-erosion-2044811.html

11 Luc Hens, Nguyen An Thinh, Tran Hong Hanh, Neo Sy Cuong, et al. "Sea-level Rise and Resilience in Vietnam and the Asia Pacific: A synthesis", *Vietnam Journal of Earth Sciences,* 40, no 2, 126–152: (2018), http://dx.doi.org/10.15625/0866-7187/40/2/11107

12 Altaf Ali Siyal, Ghulam S Solangi, Zain-ul-Abdin Siyal, et al. "Shoreline Change Assessment of Indus Delta using GIS-DSAS and Satellite data", *Regional Studies in Marine Science,* 53, 102405, (2022), https://www.sciencedirect.com/science/article/abs/pii/S2352485522001256

13 Altaf Ali Siya, "Climate change: Assessing Impact of Seawater Intrusion on Soil, Water and Environment on Indus delta using GIS & Remote Sensing Tools", US. *Pakistan Center for Advanced Studies in Water (USPCAS-W), MUET,* Jamshoro, Pakistan, (2018), https://water.muet.edu.pk/wp-content/uploads/2019/07/Report-on-Indus-Delta.pdf

14 Amin Ahmed, "Living Indus Initiative to Cost Around USD 17 billion: UN", *Dawn, Today's Paper*, 14 March 2024, https://www.dawn.com/news/1752790

15 Michalis I Vousdoukas, Roshanka Ranasinghe, et al. "Sandy Coastlines Under Threat of Erosion", *Nature Climate Change* 10, 260–263: (2020), https://doi.org/10.1038/s41558-020-0697-0

16 Coastal Restoration Toolkit, Gulf of Mexico Region, "The Problem: Protecting Human-built Structure from Coastline Erosion has been going on for Centuries", *Coastal Restoration Toolkit,* https://restoreyourcoast.org/coastalerosion/gulf/

17 Coastal Protection and Restoration Authority of Louisiana, United States, "2017 Louisiana's Comprehensive Master Plan for a Sustainable Coast: Committed to Our Coast", State of Louisiana, (2017), https://coastal.la.gov/our-plan/2017-coastal-master-plan/

18 Rongshuo Cai, Kexiu Liu, Hongjian Tan, and Xiuhua Yan, "Climate Change and China's Coastal Zones and Seas: Impacts, Risks, and Adaptation", *Chinese Journal of Population, Resources and Environment*", 19, no 4,(2021): 304-310, https://www.sciencedirect.com/science/article/pii/S2325426222000031

See Also: Nan Xu, Pen Gong, "Significant Coastline Changes in China during 1991-2015 Tracked by Landsat Data", *Science Bulletin*, 63, (2018): 883-886, https://doi.org/10.1016/j.scib.2018.05.032

19 Murray Swart, "The Longest Beach in South Africa is Quickly Disappearing", *Cape Town*, 10 January 2023, https://www.capetownetc.com/cape-town/longest-beach-sa-disappearing-fast-erosion-accelerates/#

20 Jennifer Murray, Elhadi Adam, Stephan Woodborne, Duncan Miller, et al. "Monitoring Shoreline Changes along the Southwestern Coast of South Africa from 1937 to 2020 Using Varied Remote Sensing Data and Appraoches", *Remote Sensing Journals*, 15, 2, 317: (2023). https://www.mdpi.com/2072-4292/15/2/317

21 European Commission, "Living with Coastal Erosion in Europe: Sediment and Space for Sustainability", *Eurosion*, 10 May 2024, http://www.eurosion.org/reports-online/part1.pdf

22 https://thewaterchannel.tv/thewaterblog/loose-and-gain-coastal-erosion-in-bangladesh/

23 Rajya Sabha, Ministry of Environment, Forest and Climate Change, Government of India, "Coastal Erosion in West Bengal", Unstarred Questions no 523 to be answered on 07 December 2023, https://sansad.in/getFile/annex/262/AU523.pdf?source=pqars#:~:text=It is observed that 33.6,39.6% was in stable state

24 European Commission, EU Science Hub, "Even at 1.5-degree Celsius warming, SIDS risk flooding from Sea Level Rise", *Joint Research Centre, Europa*, 05 December 2023, https://

joint-research-centre.ec.europa.eu/jrc-news-and-updates/even-15degc-warming-small-island-developing-states-risk-flooding-sea-level-rise-2023-12-05_en#:~:text=Perhaps the most concerning aspect, achieve the Paris Agreement goals

25 Chandru Badrinarayanan and Zoya Akhter, "The Cost of Climate Change: Assessing the Impact on SIDS", *Blue Sky Analytics,* 10 May 2023, https://blueskyhq.io/blog/the-cost-of-climate-changing-assessing-the-impact-on-sids-small-island-developing-states#close-cookie

26 Elna Fortune, "How Mauritius, a Small Island Developing States, is Adapting to Sea Level Rise", *Prevention Web,* 13 May 2020, https://www.preventionweb.net/news/how-mauritius-small-island-developing-state-adapting-sea-level-rise

27 IPCC, Coastal Zone Management Sub-Group, Strategies for Adaptation to Sea-level Rise, Report, Response Strategies Working Group of the IPCC, https://www.ipcc.ch/site/assets/uploads/2018/03/ipcc_far_wg_III_chapter_05.pdf

28 M Haasnoot et al, "Adaptation to uncertain sea-level rise; how uncertainty in Antarctic mass-loss impacts the coastal adaptation strategy of the Netherlands", *Environmental Research Letters* 15, 034007, (2020). https://doi.org/10.1088/1748-9326/ab666c

29 Global Centre on Adaptation, "State and Trends in Adaptation Report", 2022, https://gca.org/wp-content/uploads/2023/01/GCA_State-and-Trends-in-Adaptation-2022_Coastal-Erosion.pdf

30 Gegar Prasetya, "The Role of Coastal Forests and Trees in Protecting Against Coastal Erosion", FOA, https://www.fao.org/3/ag127e/ag127e07.pdf

31 MFF Pakistan, "Coastal Erosion in Pakistan: A National Assessment Report". MFF Pakistan, Pakistan, 52 pp, 2014. https://www.scribd.com/document/323949016/Coastal-Erosion-in-Pakistan

32 US Army Corps of Engineers, "Beach Nourishment Evaluation Report, Carolina Beach', Wilmington District, 2019, https://www.saw.usace.army.mil/Portals/59/docs/coastal_storm_damage_reduction/Carolina Beach/Carolina Beach - DRAFT Beach Renourishment Evaluation Report - USACE - June 24 2019.pdf

33 M Robertson, "Ecosystem Services", *Encyclopedia of Environmental Health*, (2011): 225-233, https://doi.org/10.1016/B978-0-444-52272-6.00416-5

34 Nature-based Solutions, Policy Platform, "Nature-based Solutions in the Revised NDCS", https://www.nbspolicyplatform.org/adaptation-planning/adaptation-action-types/nature-based-actions/

35 Emerald Tutu, About and research, website, https://emerald-tutu.com/research

36 Sete Agglopole, "The Fight Against Coastal Erosion", *AggloPole France*. http://www.agglopole.fr/wp-content/uploads/2019/03/EN.pdf

37 Thomas Thaler, "Just Retreat—how different Countries Deal with it: Examples from Austria and England", *Journal of Environmental Studies and Science,* 11, 412–419: (2021). https://doi.org/10.1007/s13412-021-00694-1, https://link.springer.com/article/10.1007/s13412-021-00694-1#Sec4

38 MFF Pakistan, "Coastal Erosion in Pakistan: A National Assessment Report". MFF Pakistan, Pakistan, 52 pp, 2014

39 Zofeen Ebrahim, "Ignored by Pakistan, the Indus Delta is being Lost to the Sea", *The Third Pole*, 2020, https://www.thethirdpole.net/en/energy/pakistan-indus-delta/

40 Chandru Badrinarayanan and Zoya Akhter, "The Cost of Climate Change: Assessing the Impact on SIDS", *Blue Sky Analytics,* 10 May 2023, https://blueskyhq.io/blog/the-cost-of-climate-changing-assessing-the-impact-on-sids-small-island-developing-states#close-cookie

41 Amin Ahmed, "Living Indus Initiative to Cost around USD 17 billion: UN", *Dawn*, 13 May 2023, https://www.dawn.com/news/1752790

42 Eric Sparks, Mississippi-Alabama Sea Grant Consortium, "About Living Shorelines", *MASGC,* https://masgc.org/living-shorelines

43 Royal Haskoning DHV, "Cultivating Oysters to Combat Coastal Erosion in Bangladesh", https://www.royalhaskoningdhv.com/en/projects/cultivating-oysters-to-combat-coastal-erosion-in-bangladesh

44 Shamsheer Yousaf, "Fusing Nature and Engineering to Save the Coast", *The Wir*e, 17 July 2023, https://science.thewire.in/environment/fusing-nature-and-engineering-to-save-the-coast

45 Government of Puducherry, Department of Science, Technology, and Environment, Puducherry Climate Change Cell (PCCC), "Restoration of Puducherry Beach", https://dste.py.gov.in/PCCC/pdf/Reports/17.pdf

46 M D Kudale, "Overview of Coastal Protection in India and Innovation Methods of Protection", *Central Water and Power Research Station (CWPRS),* Pune, https://old.cwc.gov.in/CPDAC-Website/Training/3_Coastal_Erosion_&_protection.pdf

47 https://dste.py.gov.in/PCCC/pdf/CS/1.pdf

48 Rajya Sabha, Ministry of Environment, Forest and Climate Change, Government of India, "Coastal Erosion in West Bengal", Unstarred Questions no 523 to be answered on 07

December 2023

49 CRZ Notification, MoEF&CC, Notification, 18 January 2019, New Delhi, http://crz.elaw.in/crz2019.html

50 KA Shaji, "Sea Surge on Kerala Coast: Why Expert are Calling for Nature-based Solutions", *Down to Earth,* 14 June 2021, https://www.downtoearth.org.in/news/climate-change/sea-surge-on-kerala-coast-why-experts-are-calling-for-nature-based-solutions-77431

51 Chime Youdon, "Vulnerability of Coastal Cities: An Integrated Adaptation Approach - Part 2", *National Maritime Foundation,* 2020, https://maritimeindia.org/vulnerability-of-coastal-cities-an-integrated-adaptation-approach-part-2/

Towards a Holistic Blue Economy Framework: Adoption of High-Level Principles for Blue Economy by the G20

Dr Pushp Bajaj and Dr Chime Youdon

Under India's presidency, the G20 forum achieved an important milestone in the global discourse on Blue Economy. A striking example was the *"Chennai High-Level Principles for a Sustainable and Resilient Blue/Ocean-based Economy"*,[1] unanimously adopted by G20 members at the meeting of Environment and Climate Ministers, which was held in Chennai in July 2023. This unique document provides a set of fundamental principles that can guide further development of national-level strategies and policies on Blue Economy by G20 members and other countries as well, on a voluntary basis, as per national circumstances and priorities.

The Ministerial Meeting of the Environment and Climate Sustainability Working Group (ECSWG) was chaired by the Hon'ble Minister of Environment, Forest and Climate Change of the Government of India, Shri Bhupender Yadav. The meeting saw active participation from 41 Ministers and their deputies from the G20 members and invited countries. The "Outcome Document" and "Chair Summary" of the Environment and Climate Sustainability Working Group were released at the meeting wherein the Chennai High-Level Principles for a Sustainable and Resilient Blue/Ocean-based Economy were appended as an Annex. Ten Presidency Documents were also released during the meeting, and these provided best practices and knowledge-inputs on several themes related to land restoration, biodiversity conservation, water management, marine plastic litter, blue economy, circular economy, and resource efficiency.

Indian G20 Presidency's Contribution to the Discourse on Blue Economy

Historically, most international forums (including the G20) have dealt with issues related to the ocean and the Blue Economy in a somewhat disjointed manner, as a subset of broader discussions on climate change, biodiversity conservation, or sustainable development. It was only in 2020 that the first dedicated Ocean and Climate Change dialogue was held under the aegis of the UNFCCC, while the first dedicated UN Ocean Conference was held only in 2017.

In contrast, the G20 has been far more active. G20 deliberations on ocean-related issues began soon after the "Rio+20 Conference" held in 2012. At the Hamburg G20 Summit in 2017, under the German Presidency, G20 members adopted the "G20 Action Plan on Marine Litter". Building on that momentum, the "G20 Implementation Framework for Actions Against Marine Plastic Litter" was established in 2019 under the Japanese Presidency. In the same year, the G20 also agreed upon the "Osaka Blue Ocean Vision" and committed to reducing additional pollution by marine plastic litter to zero by 2050. In 2020, the G20 took an important step towards the conservation and restoration of coral reefs with the launch of the "Coral Research and Development Accelerator Platform" (CORDAP) under the Saudi Arabian Presidency. Last year, in 2022, under the Indonesian Presidency, the "Ocean 20 Launch Event" was conducted in Bali to discuss ocean-related issues in a comprehensive manner.

The Indian Presidency, in 2023, took the metaphoric baton from Indonesia and conducted the "Ocean 20 Dialogue" in Mumbai, where cross-cutting themes of science, technology and innovation, policy and governance, and sustainable blue finance, were discussed in great detail. For the first time in the history of G20, the "Blue Economy" was added as a dedicated priority agenda point within the Environment and Climate Sustainability Working Group (ECSWG), under the Indian Presidency, to deliberate upon challenges and opportunities associated with the sustainable and equitable utilisation of coastal and marine resources. This epitomises India's commitment to elevating issues related to ocean health and the Blue Economy within the ongoing international discourse on the environment and sustainable development.

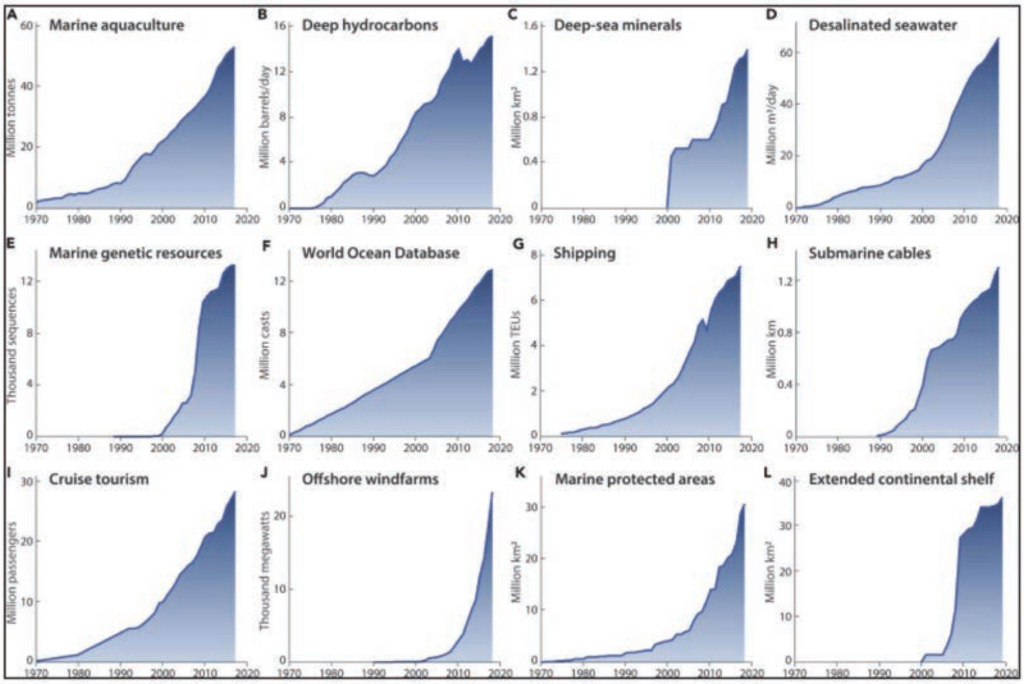
The "High-Level Principles for Blue/Ocean-based Economy" were developed through a comprehensive consultative process, which involved the active participation of the G20 member-States, invited countries, and international organisations, during all four ECSWG meetings and several virtual meetings as well. In addition to the "High-Level Principles", the Indian Presidency also produced two major knowledge outputs relevant to the Blue Economy, namely, a technical study on "Accelerating the Transition to a Sustainable and Resilient Blue Economy", jointly produced by the Ministry of Environment, Forest and Climate Change and the United Nations Development Programme (UNDP), and the 5th edition of the G20 Report on "Actions Against Marine Plastic Litter", produced by the Ministry of Environment Forest and Climate Change and supported by the Ministry of Environment of Japan.

Distinguishing Between "Blue Economy" and "Ocean Economy"

Traditionally, the ocean and its ecosystems have been viewed as sources of limitless resources and cost-free spaces to dispose-off waste, resulting in excessive use and, in some cases, irreversible changes to the coastal and marine environments. The term "Ocean Economy" has been conventionally used as an umbrella term to refer to all economic activities that take place in the coastal and marine spaces, including activities such as shipping and transportation, offshore oil and gas exploration, marine tourism and recreation, fisheries and aquaculture, marine renewable energy, and marine biotechnology. The Ocean Economy primarily emphasises the economic value generated by these activities, together with the goods and services, regardless of their impacts on the coastal and marine environments.

A 2020 study showed that nearly all of these economic activities have shown remarkable rates of growth in the last 50 years, with a sharp increase at the onset of the twenty first century — a phenomenon that is frequently referred-to as *'blue acceleration'*.[2] This can be attributed to a growing realisation by countries of the economic opportunities provided by the ocean space. Figure 1 depicts these trends in respect of marine aquaculture production, deep offshore hydrocarbon extraction, deep-sea mining for minerals, seawater desalination capacity, marine genetic resources, accumulated number of casts added to the "World Ocean Database",

Figure 1: The Blue Acceleration



Source: J B Jouffray, R Blasiak, A V Norstrom, H Osterblom, and M Nystrom, "The Blue Acceleration: The Trajectory of Human Expansion into the Ocean", One Earth Perspective No 2, 2020.

containerised port-traffic, the total length of submarine fibre-optic cables, cruise-ship tourism (number of cruise passengers), installed offshore wind energy capacity, marine protected areas, and areas of the seabed claimed as the extended continental shelf.

Unfortunately, yet predictably, this acceleration in economic activity has been accompanied by an accelerated degradation of the coastal and marine environments, caused by increasing marine pollution, overexploitation of resources, and the growing impacts of climate change including ocean warming, ocean acidification, intensifying extreme weather events, and sea level rise.

In the light of these developments, the term "Blue Economy" was first introduced at the global platform at the Rio+20 conference in 2012, as a sort of an oceanic parallel to the "Green Economy". The term "Blue Economy" emerged out of the demands of Small Island Developing States (SIDS) and other coastal nations to address the failures of the Green Economy model to adequately capture the unique characteristics and importance of the coastal and marine environments. The term therefore corresponds to a relatively novel concept which promotes the sustainable and equitable use of coastal and marine resources for economic growth and job creation, while preserving the health of the ocean and its biodiversity. Over time, the policy discussions around the Blue Economy have evolved significantly. However, different countries and organisations have contextualised the Blue Economy differently, based on their specific circumstances and priorities. This has contributed to confusion about what the term actually means. This formed the primary motivation to facilitate more deliberate discussions on Blue Economy under the Indian G20 Presidency and the need to develop a common and comprehensive set of principles to characterise the Blue Economy.

Decoding the "Chennai High-Level Principles for a Sustainable and Resilient Blue/Ocean-based Economy"

The High-Level Principles adopted by the G20 represent a crucial first step towards the development of coherent national and regional Blue Economy strategies and policies. After many hours of intense negotiations, the following nine principles were unanimously adopted by the G20:

Principle 1: Prioritise Ocean Health: Address Marine Pollution, Halt and Reverse Biodiversity Loss, and Conserve Coastal and Marine Ecosystems

Principle 2: Acknowledge and Address the Links between Ocean and Climate

Principle 3: Promote Social and Inter-generational Equity and Gender Equality

Principle 4: Promote the use of Marine Spatial Planning (MSP) for an Integrated Approach to the Blue/Ocean-based Economy

Principle 5: Leverage Science, Technology, and Innovation

Principle 6: Recognise, Protect, and Utilise Indigenous and Traditional Knowledge

Principle 7: Establish and Implement Blue/Ocean-based Economy Monitoring and Evaluation Mechanisms

Principle 8: Strengthen International Cooperation to Tackle Shared Maritime Challenges

Principle 9: Enhance Ocean Finance

A brief description of each of the principles is also provided in the final document that was released at the Ministerial Meeting.[3] Arguably, the first three principles define the core aspects of a "Blue Economy", which include the protection and preservation of the coastal and marine environments, and the promotion of social equity and gender equality. The last six principles highlight the key enablers for a sustainable and resilient Blue Economy. Importantly, the principles also lay stress upon the importance of aligning Blue Economy initiatives with the goals and targets of existing international agreements and frameworks such as the "Convention on Biological Diversity" and its recently adopted "Kunming-Montreal Global Biodiversity Framework", the "BBNJ Agreement" under UNCLOS, the UNFCCC and the Paris Agreement, the "2030 Agenda for Sustainable Development", amongst others. Indeed, pursuing a Blue Economy provides significant opportunities to contribute towards the international goals on climate change, pollution, and sustainable development.

Principle 2 explicitly highlights the need to acknowledge the interlinkages between ocean and climate, and in turn, the Blue Economy. While all sectors of the Blue Economy are directly or indirectly affected by the impacts of climate change, the Blue Economy also provides a framework to mitigate and adapt-to climate change, which is briefly outlined in Principle 2. For instance, ocean-based renewable energy could be utilised to diversify the renewable energy portfolio, particularly in land-scarce countries such as India. The conservation and restoration of coastal and marine ecosystems provide multiple benefits in the context of climate change, particularly since these ecosystems act as natural carbon sinks and also serve as natural barriers against coastal erosion and extreme weather events. Principle 3 highlights the need for Blue Economy approaches to promote social and inter-generational equity and gender equality. This is a core aspect that determines the effectiveness of any Blue Economy strategy, to facilitate effective participation of all stakeholders in the planning and decision-making processes, as also to ensure equal sharing of the benefits.

Along these lines, Principle 4 calls for an integrated approach towards the Blue/ Ocean-based Economy by employing Marine Spatial Planning (MSP), which recognises *"the full array of interactions within an ecosystem, balances diverse human uses, and takes into account the need for marine protection and conservation"*. Importantly, Principles 5 and 6 talks about the need to leverage modern science, technology and innovation, as well as the need to respect and include indigenous and traditional knowledge, cultures, and practices. Blue Economy approaches and initiatives must be informed by the latest science and facilitated by technological and social innovations to generate and implement solutions for contemporary environmental challenges.

Recognising the inherent interconnected nature of the maritime space, Principle 8 calls for enhanced international cooperation at all levels to address the shared challenges of biodiversity loss, climate change, and marine pollution. This Principle highlights the importance of capacity building, knowledge sharing, technology and the sharing of best practices and common projects and investments, amongst the G20 and beyond. Finally, Principle 9 recognises the significant financing gap facing ocean-related protection and conservation efforts and calls for the strengthening of financial resources, including for developing countries, from diverse sources — national, international, public and private. Importantly, it also emphasises the opportunities to utilise existing finance mechanisms under the UNFCCC, the Paris Agreement, and the CBD, towards ocean-related actions.

Way Forward

As mentioned earlier, different countries have contextualised the Blue Economy differently in their national policies/strategies, which may or may not cover all the fundamental aspects discussed above. Under the Indian G20 Presidency, the Ministry of Environment, Forest and Climate Change (MoEFCC) and the United Nations Development Programme (UNDP) jointly produced a technical study entitled, *"Accelerating the Transition to a Sustainable and Resilient Blue Economy"*,[4] wherein the authors identified and analysed the Blue Economy approaches of the G20 members. It was found that none of the G20 members had developed a targeted, comprehensive Blue Economy Strategy thus far. While some nations are currently in the process of formulating such a strategy, others have in place comprehensive ocean-centric strategic plans that also encompass elements of the Blue Economy. Most coastal and island countries (within G20 and beyond) have sectoral plans/strategies for individual maritime sectors, some of which may include the basic concepts of the Blue Economy.

In this regard, the "Chennai High-Level Principles on Sustainable and Resilient Blue/Ocean-based Economy" document, adopted by the G20, could serve as a starting point to shape future national and regional strategies on Blue Economy and contribute towards the generation of greater coherence amongst those strategies. The principles cover all the core aspects of sustainability, inclusivity, equity, resilience, integrated management, and finance, which together characterise the Blue Economy. Further studies could provide recommendations and technical guidance on how to effectively operationalise these principles and ensure greater harmony between future economic growth and the natural capacities of our ocean and the planet.

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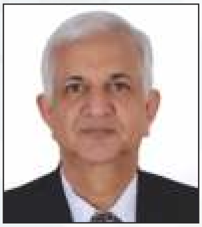
ENDNOTES

1 G20 Environment and Climate Sustainability Working Group – Chennai High Level Principle for a Sustainable and Resilient Blue/ Ocean-based Economy. https://www.g20.org/content/dam/gtwenty/gtwenty_new/document/G20_ECSWG-Chennai_Principles_for_a_BlueOcean-based_Economy.pdf

2 J B Jouffray, R Blasiak, A V Norstrom, H Osterblom, and M Nystrom, "The Blue Acceleration: The Trajectory of Human Expansion into the Ocean", *One Earth Perspective* No 2, 2020.

3 G20 Environment and Climate Sustainability Working Group – Chennai High Level Principle for a Sustainable and Resilient Blue/ Ocean-based Economy. https://www.g20.org/content/dam/gtwenty/gtwenty_new/document/G20_ECSWG-Chennai_Principles_for_a_BlueOcean-based_Economy.pdf

4 MoEFCC & UNDP, 2023. Accelerating the Transition to a Sustainable and Resilient Blue Economy. Ministry of Environment, Forest and Climate Change, New Delhi, India 91 pp. https://www.g20.org/content/dam/gtwenty/gtwenty_new/document/G20_ECSWG-Technical_Study_on_Accelerating_the_Transition_to_a_Sustainable_and_Resilient_Blue_Economy.pdf



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