Autonomous Ships And Indian Maritime Law: Challenges And Opportunities

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I. Executive Summary

The advent of **Maritime Autonomous Surface Ships (MASS)** marks a transformative era in the maritime industry, driven by cutting-edge technologies like artificial intelligence (AI), the Internet of Things (IoT), and automation. These innovations promise to enhance efficiency, safety, and environmental sustainability while reducing operational costs. Pioneering vessels such as the "**MV Yara Birkeland**" and the "**Mayflower 400**[1]" exemplify the potential of autonomous shipping to revolutionize cargo transport and oceanographic research. However, the integration of MASS into global maritime operations presents significant challenges, particularly in legal and regulatory domains. Indian maritime law, steeped in traditional seafaring practices, faces a critical need for adaptation to address complexities related to liability, insurance, and compliance with international standards. This paper examines the challenges and opportunities posed by autonomous shipping within the Indian context, emphasizing the necessity for policy reforms, technological innovation, and collaboration with global regulatory bodies. By proactively addressing these issues, India can harness the potential of MASS to achieve leadership in maritime technology and sustainable innovation.

Keywords: MASS, Indian Maritime Law, Autonomous Shipping Regulations, Maritime Technology Innovation

II. Introduction

A. Overview of Autonomous Ships[2]

Autonomous ships represent a transformative advancement in maritime technology, incorporating varying degrees of automation to support or replace human intervention in vessel operations. These ships leverage advanced technologies such as sensors, artificial intelligence (AI), and self-learning systems to navigate, detect obstacles, chart routes, and perform essential tasks. They range in size and function, from small hydrographic survey ships to large container vessels, serving purposes like goods transportation, maritime surveillance, and research.

Key Features and Benefits:

1. Enhanced Safety: By reducing human error through automation and decision-support systems, autonomous ships offer safer operations. They employ sensor fusion and AI for accurate object detection and obstacle avoidance, surpassing traditional human observation.
2. Efficiency and Speed: Autonomous ships optimize routes based on factors like weather and traffic, reducing fuel consumption and travel time. Their ability to operate continuously without breaks ensures faster and uninterrupted voyages.
3. Environmental Benefits: With fuel-efficient operations and minimized emissions, autonomous vessels contribute to greener maritime practices.
4. Innovation and Economic Growth: Autonomous technologies drive advancements in smart ports and communication systems, fostering new business opportunities and increasing competitiveness in the maritime industry.

[1] Mayflower 400

[2] Autonomus Ships

B. Relevance in Modern Maritime Industry[3]

Autonomous ships are transforming maritime operations by introducing cutting-edge technologies and redefining traditional practices. Their relevance lies in their potential to enhance efficiency, safety, and sustainability while addressing key industry challenges. They are equipped with modular control systems, sensors, and communication technologies, enabling self-steering, collision avoidance, and decision-making. Examples include the Yara Birkeland, the first fully electric autonomous container ship, and the AI-powered Mayflower Autonomous Ship for research missions.

Broader Impacts:

1. Economic Efficiency: Reduced operational expenses and greenhouse gas emissions contribute to cost-effective international trade.
2. Workforce Evolution: Automation shifts crews' focus from routine tasks to more demanding responsibilities, improving job satisfaction and retention.
3. Proven Applications: Autonomous vessels have demonstrated safety and utility in navigation, research, military, and underwater operations.

As technology advances and regulatory frameworks mature, autonomous ships are poised to become integral to global trade. Their adoption will drive efficiency, safety, and sustainability, marking a new era in maritime industry practices.

C. Importance of Addressing Legal Challenges[4]

The importance of addressing legal challenges related to autonomous ships lies in their transformative potential for the maritime industry, coupled with the significant gaps in existing legal frameworks. Maritime Autonomous Surface Ships (MASS) promise enhanced efficiency, reduced operational costs, and improved safety, but their integration faces substantial hurdles due to outdated regulatory instruments like the **United Nations Convention on the Law of the Sea (UNCLOS)**[5] and the International Maritime Organization (IMO) regulations, which are tailored for manned vessels.

Key legal challenges:

1. Defining Responsibility and Liability: Determining the "master" of an autonomous ship is complex, especially when traditional maritime laws assign specific duties to the onboard crew. For fully autonomous or remotely operated vessels, liability in cases of accidents or regulatory breaches remains unclear.
2. Safety and Collision Avoidance: Current conventions like SOLAS[6] and COLREGS[7] assume human decision-making, posing challenges in adapting rules for autonomous operations. Autonomous systems must demonstrate the ability to navigate and avoid collisions under varied conditions.
3. Cybersecurity Risks: Autonomous ships are vulnerable to cyberattacks, which could lead to navigation failures or hijacking. Addressing these risks requires robust cybersecurity frameworks.

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[3] Relevance
[4] Legal Challenges
[5] UNCLOS
[6] SOLAS
[7] COLREGS

4. Regulatory Harmonization: Disparities in regulatory approaches across nations can create inconsistencies, potentially hindering global trade and innovation in autonomous shipping.
5. Search and Rescue (SAR) Obligations: Legal frameworks must clarify how autonomous vessels will fulfill SAR duties, a core tenet of maritime law.

Addressing these challenges through updated regulations, international cooperation, and rigorous safety standards is vital to harnessing the full potential of MASS while ensuring maritime safety, security, and environmental compliance.

III. What are Autonomous ships?

A. Definition[8] and Classification[9]

Autonomous ships, also known as Maritime Autonomous Surface Ships (MASS), are vessels equipped with advanced automation systems that enable them to operate with varying degrees of human intervention. Autonomy in this context refers to the ability of the ship to make decisions and perform tasks without direct human control, ranging from automated navigation to fully independent operations.

Classification: The International Maritime Organization (IMO) has proposed four degrees of autonomy for MASS:

1. Degree 1: Ship with Automated Processes and Decision Support:
   - **a.** Seafarers are present on board and can take control when necessary.
   - **b.** Some operations may be automated and temporarily unsupervised.
2. Degree 2: Remotely Controlled Ship with Seafarers Onboard:
   The ship is operated from a remote location, but seafarers remain onboard to handle emergencies.
3. Degree 3: Remotely Controlled Ship without Seafarers Onboard:
   Entirely operated from shore control centers, with no crew onboard.
4. Degree 4: Fully Autonomous Ship:
   The ship operates independently without human intervention, making decisions autonomously based on onboard systems.

Other classifications include:

1. Periodically Unmanned Bridge (PUB): Ships with unmanned bridges during specific periods, such as in open seas under calm weather conditions.
2. Continuously Unmanned Ship (CUS): Ships designed for full unmanned operation except during emergencies.
3. Constrained Autonomous Ships: Vessels with predefined operational limits and fallback procedures in case they encounter situations beyond their programmed capabilities.

[8] Definition
[9] Classification

IV. Global Trends in Autonomous Shipping

A. Adoption Across Key Maritime Nations

The adoption of digital and environmental policies in the maritime sector has been gaining momentum among key maritime nations due to increasing concerns over operational efficiency, environmental sustainability, and economic pressures.

1. Digital Adoption and Efficiency in Maritime Industry[10]

   The COVID-19 pandemic accelerated digital transformation in the maritime sector, highlighting the strategic importance of technology in improving efficiency. Maritime firms in countries with advanced technological ecosystems have adopted digital solutions like broadband internet, sophisticated cloud computing, and enterprise resource planning systems. Cross-country firm-level data from EU member states (2015–2020) demonstrates that digital adoption has led to significant multi-factor productivity (MFP) growth. Larger firms and those engaged in water transport activities derived the most benefits, whereas smaller firms and warehousing/support sectors showed slower progress.

   a. Digital technologies observed include broadband internet (0.34 average usage index), enterprise resource planning (0.33), and sophisticated cloud computing (0.12).

   b. Efficiency gains were more significant in routine-intensive industries, which streamlined operations using digital tools.

2. Adoption of Maritime Environmental Policies[11]

   Environmental concerns have led to the adoption of strict policies like **Emission Control Areas (ECAs)** to mitigate air pollution caused by shipping. ECAs are designated maritime zones where stricter environmental regulations apply to reduce air pollution from ships. These regulations, established under the International Maritime Organization's (IMO) MARPOL Annex VI, target pollutants such as sulphur oxides (SO_x), nitrogen oxides (NO_x), and particulate matter. Ships operating in ECAs must use cleaner fuels with low sulphur content or adopt alternative technologies like scrubbers to meet emission standards. They are relevant because they aim to improve air quality, protect human health, and mitigate environmental impacts, particularly in coastal and densely populated areas. By reducing harmful emissions, ECAs contribute to combating climate change and preserving marine ecosystems. However, ECAs have limitations, including the high compliance costs for ship operators, which may increase shipping expenses. Enforcement challenges and disparities in fuel availability can also hinder effectiveness. Additionally, ECAs are geographically restricted, leaving other maritime regions without similar protections.

   The Mediterranean Sea, surrounded by 21 countries, adopted a **Sulphur Emission Control Area (SECA)** in 2022 after nearly two decades of negotiation and collaboration through regional and international bodies.

[10] Adoption

[11] Environmental Policy

Case Study: Mediterranean SECA[12]

The Mediterranean Sulphur Emission Control Area (SECA) focuses on the implementation of regulations to limit sulphur emissions from ships operating in the Mediterranean Sea, in line with International Maritime Organization (IMO) standards. As a designated SECA, the region mandates the use of low-sulphur fuels or alternative technologies to reduce sulphur oxide (SO_x) emissions, aiming to combat air pollution and protect public health and the environment. The Mediterranean SECA case highlights how nations coordinated efforts through frameworks like the Barcelona Convention and the International Maritime Organization (IMO) to reach a consensus. The policy aims to reduce sulphur emissions and improve air quality, reflecting a commitment to sustainable maritime practices.

a. The first SECA was established in the Baltic Sea in 2005, followed by others in the North Sea, North America, and the Caribbean.

b. Within the Mediterranean region, more than 30,000 ships operate annually, contributing significantly to regional air pollution.

c. Adoption required consensus-building, technical studies, and political alignment among Mediterranean countries.

3. Stakeholder Engagement in Maritime Policy[13]

Stakeholders across the maritime value chain—ranging from government bodies and international organizations to industry players and NGOs—played a critical role in driving policy adoption. Collaborative efforts helped overcome resistance to change, particularly from shipping firms concerned about increased operational costs.

a. Policy entrepreneurs and environmental NGOs actively pushed for stricter regulations by conducting studies and raising awareness.

b. The European Union emerged as a key driver in shaping maritime environmental policies by aligning regional priorities with global standards.

The adoption of digital and environmental policies across key maritime nations demonstrates a dual focus on enhancing operational efficiency and environmental stewardship. While digital transformation continues to drive productivity in shipping, regional collaborations like the Mediterranean SECA underline the importance of international cooperation in tackling shared environmental challenges. Moving forward, maritime nations are likely to deepen investments in digital solutions and green technologies to remain competitive and compliant with evolving global standards.

B. Regulatory Developments by the International Maritime Organization (IMO)[14]

The International Maritime Organization (IMO) has played a crucial role in advancing maritime regulatory frameworks, aligning its efforts with the requirements of the United Nations Convention on the Law of the Sea (UNCLOS) of 1982. One of its significant contributions has been the enhancement of Port State Control (PSC) measures. In 1995, the IMO adopted new procedures to strengthen PSC under the conventions SOLAS 1974 and MARPOL 73/78, extending inspections to operational

[12] SECA

[13] Stakeholders

[14] Regulatory Developments

aspects of ships. These measures aim to address issues with substandard vessels and improve enforcement by ensuring that inspectors are highly qualified, thereby mitigating concerns of bias or undue burden on shipowners.

Another area of focus has been pollution arising from seabed activities under national jurisdiction, addressed in Article 208 of UNCLOS. While the IMO has supported regional efforts to develop harmonized environmental regulations, it has not yet pursued additional global frameworks in this area. The Commission on Sustainable Development (CSD) has been encouraged to review the need for further measures, recognizing the IMO's expertise to contribute to future developments if required.

Land-based sources of marine pollution, identified as the most significant contributors to environmental degradation, have seen limited regulatory progress under Article 207(4) of UNCLOS. The 1995 Washington Declaration and the Global Programme of Action called for binding international instruments to reduce emissions of persistent organic pollutants. Despite these efforts, comprehensive global rules remain challenging to establish due to the complexity and scope of the problem.

The IMO has also addressed offshore oil and gas exploration activities, primarily through safety codes and guidelines for installations. These measures focus on safety and environmental protection, though global regulations specific to pollution from these activities remain under discussion. The IMO's approach has been to balance regional implementation with broader international oversight, leaving room for adjustments based on evolving needs.
In 1995, the IMO consolidated its regulatory advancements into a single comprehensive guidance document, providing detailed procedures for technical inspections, safety protocols, and pollution control measures. This effort highlights the IMO's commitment to ensuring maritime safety, environmental protection, and adherence to UNCLOS, while addressing emerging challenges in global maritime governance.

V. The Indian Maritime Sector: Current Landscape[15]

India's maritime sector plays a critical role in its trade and energy security, with 95% of trade by volume and 70% by value conducted via sea routes. The Indian Ocean Region (IOR) is central to global commerce, connecting three continents and hosting vital trade routes. India is a significant contributor to global maritime activities, being the third-largest provider of seafarers and ship recycling by tonnage.

Key Developments and Policies:

1. Infrastructure Modernization:
   - **a.** Enhanced port infrastructure and cargo handling via initiatives like Sagarmala and Maritime India Vision (MIV) 2030.
   - **b.** Upcoming ports like Vadhavan and Vizhinjam are poised as growth engines.
   - **c.** Adoption of smart technologies such as AI, IoT, and blockchain for improved efficiency and sustainability at ports.

[15] Indian Maritime

2. Green and Sustainable Practices: "Harit Sagar"[16] guidelines promote green ports with clean energy, reduced emissions, and sustainable operations, aligning with India's net-zero goals by 2070.
3. Legislative Push: Five key bills (e.g., Merchant Shipping Bill, Coastal Shipping Bill) aim to redefine the maritime framework.
4. Fleet Expansion and Financial Incentives:
   a. Target to increase Indian-owned ships to 1,000 within a decade.
   b. Establishment of IFSC in GIFT City and proposal for infrastructure status for shipping to attract investments.
5. Comprehensive Logistics and Connectivity:
   a. Initiatives like PM GatiShakti[17] and National Logistics Portal foster integrated multimodal transport. PM GatiShakti is an initiative by the Government of India to enhance infrastructure and logistics efficiency by integrating 16 ministries on a digital platform. Using GIS-based tools, it enables real-time monitoring, coordinated planning, and faster implementation of projects like roads, railways, and ports. The goal is to improve supply chains, reduce costs, and support sustainable economic growth.
   b. Development of inland waterways and better last-mile connectivity.
6. Skill Development and Innovation:
   a. Support for maritime education and executive programs to cultivate a skilled workforce.
   b. Creation of maritime clusters for industry collaboration.
7. Institutional Support: Establishment of Maritime Development Fund and Indian Maritime Centre to promote investment and streamline policies.

India's maritime sector is undergoing a transformation marked by modernization, sustainability, and robust policy support. These initiatives aim to restore India's historical maritime prominence and position it as a global leader in trade, logistics, and shipping.

A. Overview of Indian Shipping Industry[18]

The Indian shipping industry is a critical component of the nation's trade and economic infrastructure, handling approximately 95% of trade by volume and 70% by value. With 12 major and 187 minor ports, the industry plays a pivotal role in connecting India to global markets. As of 2010, India ranked among the top 20 countries in terms of merchant fleet size, operating over 1,000 ships with a gross tonnage of 10.1 million GT.

Despite growth, the sector faces challenges such as high port congestion, outdated ship technology, and limited LNG transport capabilities. The Indian government has introduced several initiatives to modernize port infrastructure, enhance shipbuilding capacity, and address environmental concerns like CO2 emissions. The integration of shipping with global logistics chains and the development of specialized ports, such as LNG terminals, remain strategic priorities.

[16] Harit Sagar Guidelines
[17] PM GatiShakti
[18] Shipping Industry

The industry's development is critical for sustaining India's international trade and reducing foreign exchange outflow on freight payments, while fostering domestic economic growth and employment in allied sectors like shipbuilding and repair.

B. Existing Maritime Laws and Policies[19]

1. Merchant Shipping Act, 1958:

It was enacted to regulate India's maritime sector, addressing various issues related to ship registration, manning, safety, pollution control, and the liability of shipowners. While it has played a crucial role in ensuring maritime safety and governance, the Act's provisions have become outdated, especially considering the rapid advancements in shipping technology and international maritime regulations.

- **a.** The Act facilitates the registration of Indian ships and sets guidelines for crew engagement. However, with the rise of autonomous ships and digital maritime systems, there is a need to update the criteria for ship registration and manning to reflect modern technologies and automated operations.
- **b.** The Act addresses the safety of passenger and cargo ships but could be improved to incorporate advanced safety protocols, especially for emerging technologies such as autonomous vessels. Additionally, the 2002 amendments limiting shipowners' liability need to be reassessed in light of the increasing complexity of shipping operations and environmental concerns.
- **c.** While the Act covers pollution control, stricter regulations are required to address marine pollution from shipping, especially regarding emissions and waste management, which are governed more by international conventions (e.g., MARPOL).

2. Carriage of Goods by Sea Act, 1925:

It is based on the Brussels Convention and Hague Rules, provides a foundational framework for regulating the transportation of goods by sea under a bill of lading. It specifies the obligations of carriers, including ensuring the seaworthiness of ships, proper handling of cargo, and adherence to liability limitations. While the Act has served as a cornerstone of maritime trade, it requires modernization to address contemporary challenges in shipping and align with global standards.

- **a.** The Act mandates carriers ensure ship seaworthiness and proper cargo care, but advancements in shipping technology and containerization require updated provisions to reflect modern logistics practices.
- **b.** The liability framework is rooted in historical contexts, often inadequate for addressing large-scale claims related to cargo damage or delays in today's high-value global trade.
- **c.** The Act's basis on the Hague Rules does not fully align with newer conventions like the **Hague-Visby Rules**[20] or **Rotterdam Rules**[21], which better address modern shipping practices, electronic documents, and multimodal transport.

3. Multimodal Transportation of Goods Act, 1993:

It was enacted to streamline the movement of goods using multiple modes of transport for exports

[19] Maritime Laws
[20] Hague Visby Rules
[21] Rotterdam Rules

from India. It establishes the responsibilities and liabilities of Multimodal Transport Operators (MTOs), ensuring accountability for delays and damages while exempting liability if no fault is proven. While the Act facilitates efficient logistics for global trade, it requires modernization to address current challenges and enhance its effectiveness.

a. The Act's liability framework, exempting MTOs unless fault is proven, may leave exporters inadequately protected in cases of damage or delay due to systemic or technical issues.

b. The Act does not account for the advancements in digital logistics systems, such as real-time tracking and electronic documentation, critical for managing modern supply chains.

c. While aligned with the UN Convention, the Act does not fully address recent international practices and agreements, potentially limiting its global applicability and competitiveness.

4. The Admiralty (Jurisdiction and Settlement of Maritime Claims) Act, 2017:

It modernizes outdated British-era maritime laws, granting Indian High Courts jurisdiction over a wide range of maritime claims. These include ownership disputes, mortgages, collisions, repairs, and environmental damage, applicable to vessels within Indian territorial waters. While the Act aligns with contemporary maritime practices and enhances judicial clarity, there are areas that require further refinement to ensure its effectiveness and alignment with global standards.

a. The Act empowers High Courts to address a wide spectrum of claims, fostering clarity in maritime dispute resolution. However, the scope may not fully cover modern claims like those involving autonomous vessels or cybersecurity threats in maritime operations.

b. While applicable to all vessels, the Act's limited exceptions could lead to ambiguities, especially concerning foreign vessels and government-owned ships.

c. The Act could better align with international conventions, such as the International Convention on Arrest of Ships, to improve enforceability and harmonization with global maritime laws.

5. Major Ports Authorities Act, 2021:

The **Major Ports Authorities Act, 2021** replaces the Major Port Trusts Act, 1963, to grant greater autonomy to India's major ports, enabling them to independently set tariffs and manage operations. It introduces an Adjudicatory Board for dispute resolution and aims to revive stressed Public-Private Partnership (PPP) projects, promoting a market-driven pricing mechanism for terminal operators. While the Act modernizes port governance, certain areas require attention to ensure seamless implementation and global competitiveness.

a. The Act empowers major ports to make operational and financial decisions independently, fostering efficiency and competitiveness. However, this autonomy may lead to discrepancies in pricing and competition between ports.

b. The establishment of the Adjudicatory Board addresses disputes effectively, but its operational framework and jurisdiction need clearer definitions to avoid overlapping with existing regulatory bodies.

c. While the Act focuses on stressed PPP projects, it lacks detailed guidelines for evaluating and implementing corrective measures.

d. The shift to market-driven pricing benefits operators but may lead to concerns over affordability and transparency, especially for smaller cargo handlers.

C. Technological Readiness for Autonomous Vessels

India has shown steady progress in adopting and developing technologies for autonomous vessels. While significant challenges remain, the maritime industry, government initiatives, and collaborations with private stakeholders are laying the groundwork for integration.

1. Infrastructure and Research
   a. India has developed maritime clusters under initiatives like the Sagarmala Programme, focusing on enhancing port infrastructure, logistics, and coastal economic zones. While these clusters aim to boost traditional shipping, they are being adapted for emerging technologies, including autonomy in maritime operations.
   b. Institutions like the Indian Maritime University (IMU)[22] and private technology hubs are engaging in research on maritime automation, albeit at an early stage compared to global leaders like Norway and Japan. Example: **National Institute of Ocean Technology (NIOT)**[23] conducts projects related to remote-controlled and autonomous underwater vehicles, contributing indirectly to autonomous surface ship development.
2. Regulatory Framework and Policy Support
   a. India has started aligning with the International Maritime Organization (IMO) standards, such as Guidelines for Maritime Cyber Risk Management and provisions for MASS testing. However, a dedicated framework for autonomous vessel operations is still in development.
   b. Aimed at modernizing the maritime sector, the Sagarmala initiative is creating a conducive environment for technological advancements, including the deployment of autonomous vessels in coastal and inland waterways.
3. Technological Capabilities
   a. India is advancing in the development of satellite-based communication and navigation systems essential for autonomous shipping. Example: **GAGAN (GPS Aided Geo Augmented Navigation)**, developed by ISRO and AAI, is improving precision in navigation and can support autonomous maritime operations.

[22] IMU
[23] NIOT

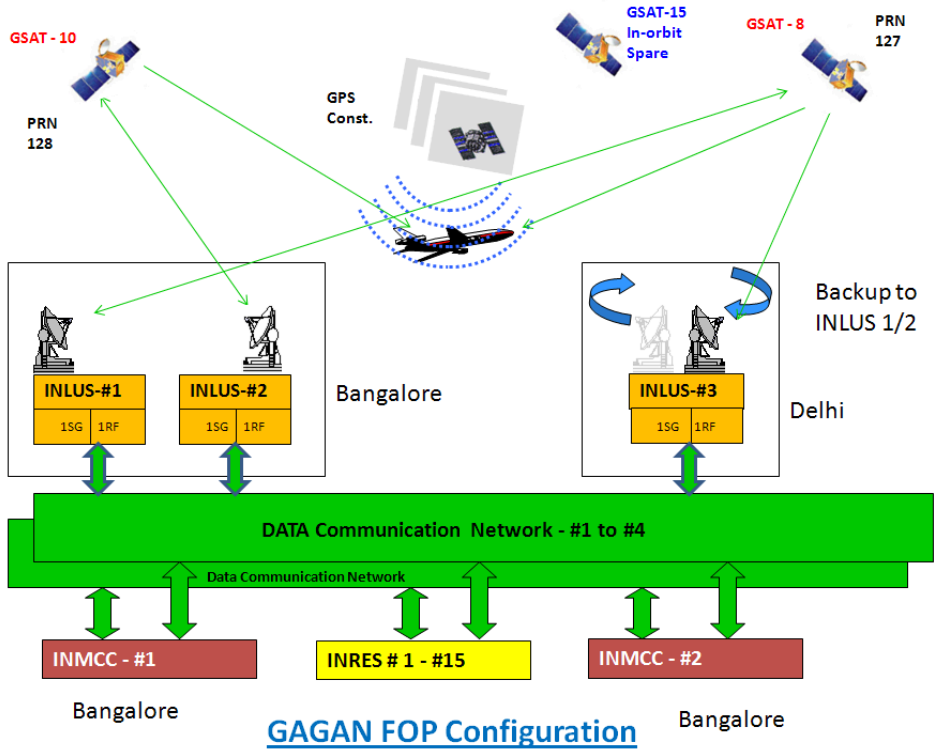

Image 1: GAGAN FOP Configuration[24]

b. Ports like JNPT (Jawaharlal Nehru Port Trust) are adopting smart technologies, including automated berthing and cargo handling systems, which provide foundational capabilities for autonomous operations.

4. Emerging Collaborations

India is leveraging PPP models to encourage investment in research and development for autonomous technologies. Collaborations with international firms and shipbuilders have facilitated the transfer of know-how. Example: Partnerships with companies like L&T Defence and Cochin Shipyard Limited are fostering innovation in maritime automation.

D. Analysis of India's Geopolitical Role in Autonomous Shipping[25]

1. Hedging and Strategic Autonomy in Maritime Technology

India's strategic hedging allows it to collaborate with multiple global partners, ensuring it stays at the forefront of technological advancements, including autonomous shipping, without alienating any major power. This aligns with its broader goals of preserving autonomy and achieving great power status. By engaging with entities like the United States for technological and defense collaboration, India can enhance its capabilities in autonomous shipping while maintaining partnerships with Russia and China, key players in global trade and maritime innovation.

2. Indo-Pacific Focus

The Indo-Pacific is a central theater for autonomous shipping development due to its vast maritime trade routes. India's policy of pursuing a free, open, and inclusive regional order underscores its interest in leveraging autonomous shipping to bolster trade and security in the region. Partnerships through

[24] GAGAN
[25] India's Hedging Policies

platforms like the Quadrilateral Security Dialogue (Quad) could facilitate India's adoption of cutting-edge technologies, ensuring its influence in shaping norms and regulations for autonomous shipping in this strategically vital region.

3. Soft-Balancing through Multilateral Engagements

   India's active participation in organizations such as BRICS, Shanghai Cooperation Organisation (SCO), and G20 provides a platform for promoting global standards and cooperation in autonomous shipping. These engagements allow India to access diverse technological expertise while avoiding alignment with any single bloc. This multilateral approach reflects India's preference for soft-balancing and inclusive diplomacy.

4. Economic and Strategic Maritime Dimensions

   Autonomous shipping directly ties into India's trade and energy security. Increased trade with China and Russia underlines India's pragmatic approach to hedging, even as it seeks strategic partnerships with the West. By advancing autonomous shipping capabilities, India could reduce logistical costs, enhance its maritime competitiveness, and secure critical sea lanes of communication.

VI. Challenges of Ships under Indian Maritime Law[26][27]

India faces multifaceted maritime security challenges categorized into military, economic, political, and environmental dimensions. These challenges, rooted in traditional and non-traditional threats, significantly impact the maritime domain and Indian maritime law.

Military Challenges

Military threats to maritime security include conventional conflicts, asymmetrical warfare, and terrorism. Armed groups and terrorists have historically targeted ships, ports, and coastal facilities. For instance, the 2008 Mumbai attacks highlighted vulnerabilities in India's coastal security. Planned attacks, such as those involving jihadi divers to strike Indian facilities, underscore the persistent risk. Additionally, hijacking of naval vessels, hostage situations, and attacks on warships and civilians remain critical threats, necessitating robust maritime defense mechanisms.

Economic Challenges

The sea lanes are crucial for India's trade and economic interests, making their security paramount. Piracy, smuggling, and illegal exploitation of resources disrupt trade routes and pose economic risks. Moreover, China's String of Pearls policy and its influence in the Indian Ocean through infrastructure projects and strategic investments in neighboring countries, such as Sri Lanka and Pakistan, challenge India's maritime sovereignty and economic security. These efforts, coupled with China's Belt and Road Initiative (BRI), intensify competition and security concerns in the region.

Political Challenges

Political issues include disputes over maritime territories, resource exploitation, and the management of shared resources. India's political strategy prioritizes a rules-based order to ensure maritime governance

[26] Challenges
[27] Challenges

and resolve disputes. However, external pressures, such as China's expanding footprint in the region, complicate matters. China's strategic partnerships with India's neighbors create geopolitical challenges that necessitate diplomatic and military responses.

Environmental Challenges

Environmental factors, including climate change, water pollution, and extreme weather events, adversely affect maritime security. Rising sea levels and unpredictable weather conditions disrupt naval operations and endanger marine biodiversity. Illegal fishing practices and overexploitation of resources exacerbate environmental degradation, complicating efforts to maintain ecological balance and sustainable livelihoods for coastal communities.

International Regulatory Challenges

India adheres to international frameworks such as the International Ship and Port Facility Security (ISPS) Code, which emerged after the 9/11 terrorist attacks. However, implementing these regulations and ensuring compliance amidst evolving threats remains an ongoing challenge.

A. Compliance with International Conventions[28]

Ensuring maritime safety involves adherence to a range of international treaties, including the SOLAS Convention and its mandatory codes (e.g., ISM, ISPS, FSS), COLREG, Load Lines Convention, STCW, and the SAR Convention. These frameworks govern various aspects of ship safety, such as structural integrity, fire prevention, cargo handling, navigation, crew training, and emergency response. Autonomous ships must meet the safety standards equivalent to conventional ships, which presents unique challenges. Their compliance involves transferring operational risks from human crew to sensors and cyber-physical systems, ensuring stability, collision avoidance, and resilience to unauthorized access. Cargo management, system reliability, and cybersecurity are critical for autonomous operations.

However, current regulations are not fully equipped to address the complexities of autonomous shipping. Challenges include:

1. Evolving Technology: Rapid advancements make standardization difficult.
2. Operational Complexity: Existing rules need updates to accommodate autonomous systems.
3. Jurisdictional Issues: Vessels and remote operation centers may fall under different national regulations.

B. Liability[29] and Insurance Concerns[30]

Liability Concerns

The advent of MASS raises complex liability questions due to the absence of human operators, challenging traditional fault-based maritime liability frameworks. Liability in the maritime sector historically hinges on human agency—assigning fault for collisions, cargo damage, and pollution based on negligence or strict liability. However, autonomous vessels, particularly those with self-learning AI systems, complicate this approach.

[28] Compliance
[29] Liability
[30] Insurance

1. Fault-Based vs. Strict Liability:
   a. Fault-based liability (common in collision and cargo damage cases) becomes difficult to apply when autonomous decisions are made by algorithms, often operating without human intervention.
   b. Strict liability emerges as a feasible alternative, where the shipowner is held accountable regardless of fault. This approach is akin to regimes in pollution control and passenger injury claims, ensuring compensation for third parties while providing legal clarity.

2. Transparency and Agency:
   a. AI systems' decision-making processes (the "black box" problem) obscure fault attribution. The lack of transparency necessitates either legal reform or new liability paradigms that address these technological challenges.
   b. Autonomous operations often involve multiple parties—shipowners, system suppliers, and remote operators—raising questions about shared responsibility and the scope of liability for errors or defects.

3. Jurisdictional Complexities:
   MASS operations span multiple national jurisdictions, complicating liability determination. For instance, a remote operator and the vessel may be subject to different legal regimes, potentially creating gaps in accountability.

4. Collision Avoidance and Compliance:
   Existing frameworks, such as the COLREGs, mandate adherence to collision avoidance rules. Autonomous ships must either replicate human decision-making or exceed it. Failures could render them unseaworthy, leading to liability for resulting damages.

Insurance Concerns

1. Adaptation of Insurance Markets:
   a. Marine insurers anticipate insuring MASS but demand clear regulatory standards. Flag state requirements and third-party verifications by classification societies currently guide underwriting, pending international frameworks like the MASS Code.
   b. Novel risks introduced by MASS (e.g., cyberattacks, system failures) necessitate specialized terms, including exclusions for design flaws and error-related liabilities.

2. Risk Assessment and Operational Data:
   Insurers may require operational data to assess risks and claims, replacing traditional evidence like crew statements. This data-driven approach could reshape premium structures and underwriting practices.

3. Cyber Risks and Coverage:
   Cybersecurity is a primary concern for MASS. While existing insurance products cover many risks, gaps remain, particularly for non-physical damages (e.g., software failures). Buy-back options for cyberattack exclusions offer partial solutions.

4. Design and System Liability:

   Insurers may focus on system suppliers for recourse in design-related claims. Smaller technology providers may face barriers due to increased financial scrutiny, potentially stifling innovation.

C. Cybersecurity and Data Privacy Risks[31]

Cybersecurity Risks

1. **Expanded Attack Surface with Increasing Autonomy**

   As the level of automation rises, the complexity of shipboard systems and their reliance on digital communication increase. This results in a larger attack surface, making autonomous ships more vulnerable to cyber threats.

2. **Nine Threat Categories for Autonomous Ships (Identified by NATO CCDCOE)[32]:**
   - **a.** Disruption of RF Signals: Jamming attacks can hinder communication between ships and shore control centers (SCC).
   - **b.** Deception or Degradation of Sensors: GNSS spoofing and radar interference can mislead navigation systems.
   - **c.** Interception or Modification of Communication Streams: Attackers can eavesdrop, alter, or replay commands sent between the ship and SCC.
   - **d.** Attacks on Operational Technology (OT) Systems: Legacy OT systems lack encryption, making them susceptible to unauthorized control.
   - **e.** Attacks on Information Technology (IT) Systems: Disruption or data breaches in IT systems can impact logistics and operations.
   - **f.** Cyber Assaults on AI Systems: Poisoned datasets or compromised models could lead to erroneous decision-making by onboard AI.
   - **g.** Supply Chain Attacks: Malicious components introduced during production or software updates can compromise the entire vessel.
   - **h.** Physical Access Attacks: Gaining direct access to shipboard systems can allow an adversary to control critical operations.
   - **i.** Attacks on the Shore Control Center (SCC): Disrupting the SCC could lead to a complete loss of control over the autonomous vessel.

3. **Specific Cyberattack Techniques**
   - **a.** Malicious Code Injection via network infiltration or removable devices (USB, firmware updates).
   - **b.** Tampering with Intra-Vessel Networks to manipulate data packets.
   - **c.** GNSS and AIS Spoofing to alter the perceived position and identity of the vessel.
   - **d.** Signal Jamming to disrupt communication and sensor functionality.
   - **e.** Eavesdropping on Communications to steal sensitive information or monitor vessel activities.

[31] Cybersecurity risks

[32] Threat Categories

4. **Complexity of Defending Against Attacks**

   Defending autonomous ships requires constant monitoring, secure design practices, and robust countermeasures such as encryption, redundant systems, and AI-driven anomaly detection.

Data Privacy Risks

1. **Sensitive Data Collection and Transmission**

   Autonomous ships gather extensive data, including environmental conditions, cargo information, and crew/passenger details. This data is transmitted to SCCs for analysis and decision-making. Without proper encryption and access controls, sensitive information can be intercepted or leaked.
2. **Vulnerability of Remote Monitoring Systems**

   Ship-to-shore communication systems used for remote monitoring are a key target for attackers. Breaches can expose operational data or allow unauthorized entities to gain insight into ship movements and cargo.
3. **Threats to Passenger and Crew Data**

   Onboard systems that handle passenger services or crew welfare (e.g., internet access, administrative tasks) can expose personal data. If compromised, attackers could misuse this information for identity theft or blackmail.
4. **Supply Chain Data Breaches**

   The involvement of multiple third parties in shipbuilding and operation increases the risk of data privacy violations through supply chain vulnerabilities. Malicious actors can introduce backdoors or gather confidential data during component development.

VII. Opportunities for India in the Autonomous

A. Enhancing Maritime Efficiency and Safety

Autonomous ships offer real-time decision-making capabilities through advanced technologies like AI, IoT, and big data analytics. These systems can improve route optimization, reduce delays, and minimize human errors.

1. India's vast coastline and busy ports (handling 95% of its trade by volume) will benefit significantly from enhanced navigational safety and operational precision, reducing incidents such as collisions and grounding.
2. Maritime Vision 2030[33] aims to improve port efficiency, which aligns with adopting autonomous systems to enhance cargo handling and reduce turnaround times.

B. Reducing Operational Costs and Environmental Impact

Autonomous vessels reduce crew requirements, cutting operational costs significantly, especially for long voyages. Moreover, their use of electric propulsion and optimized fuel consumption can lower carbon emissions.

1. As a signatory to IMO's greenhouse gas (GHG) strategy[34], India is committed to reducing emissions. Deploying autonomous vessels with green technologies can help achieve these targets.

[33] Maritime India Vision 2030

[34] IMO GHG Emission Strategy

2. Autonomous ships like Norway's Yara Birkeland[35] demonstrate potential savings of 40-50% on fuel and operational costs.
3. Reduced emissions align with India's Harit Sagar initiative, promoting sustainable and green ports.

C. Boosting Innovation and Technological Development

Adopting autonomous technologies can stimulate domestic innovation in robotics, AI, and sensor systems. It will also encourage collaborations between technology providers, shipbuilders, and educational institutions.

1. Programs like Sagarmala and Atmanirbhar Bharat aim to enhance local manufacturing and self-reliance, creating a fertile ground for innovation in maritime technologies.
2. By promoting research and development (R&D), India could establish maritime technology hubs, fostering startups and attracting global investments.

D. Positioning India as a Global Leader in Maritime Technology

With a strategic location in the Indian Ocean Region (IOR) and a significant maritime workforce, India has the potential to become a global hub for autonomous shipping.

1. By adopting autonomous ship technologies early, India can compete in the $100+ billion global maritime technology market.
2. India already supplies 10% of the world's seafarers[36]. Upskilling this workforce for operating and maintaining autonomous systems can further its dominance in maritime human resources.
3. Collaborations with Quad members (e.g., U.S., Japan) on maritime security and technology provide India a platform to showcase leadership in autonomous systems.

VIII. The Way Forward: Adapting Indian Maritime Law

A. Recommendations for Policy and Legislative Reforms

1. Updating Legal Frameworks

   India's maritime laws, including the **Merchant Shipping Act, 1958** and the **Admiralty Act, 2017**, must be amended to define operational standards, safety protocols, and liability for Maritime Autonomous Surface Ships (MASS). It should include:

   a. Transition from fault-based liability to strict liability for incidents involving autonomous vessels. This approach ensures clarity and aligns with global conventions like the **Civil Liability[37] for Oil Pollution Damage (CLC) Convention**.
   b. Expand the legal definition of "seaworthiness[38]" to incorporate the reliability and resilience of autonomous systems, ensuring vessels are safe for operations without direct human intervention.
   c. Establish protocols for the certification, monitoring, and decommissioning of autonomous systems.
   d. It should include regulations for autonomous ships, including registration, operational standards, and crew requirements.

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[35] Yara Birkeland
[36] Seafarers
[37] Civil Liability
[38] Seaworthiness

e. Adopt stricter domestic regulations aligned with international conventions like MARPOL to reduce emissions, discharge, and sustainable shipping practices.

f. Implement provisions for digital navigation systems, cybersecurity, and data-sharing protocols to improve efficiency and security in maritime operations.

g. Ensure the Act aligns with global maritime standards, collaborating with international bodies to facilitate smoother trade and compliance for Indian shipping.

h. Define exceptions more clearly, particularly for government-owned or foreign vessels, to avoid interpretational conflicts and ensure fair treatment in disputes.

i. Harmonize with international conventions, ensuring seamless enforcement of judgments and compatibility with global maritime legal frameworks.

j. Establish dedicated maritime benches within High Courts or specialized tribunals for faster resolution of complex maritime claims.

2. Incorporating Cybersecurity Standards

Autonomous vessels rely on complex digital systems, making them susceptible to cyber threats[39]. India's maritime policies must integrate robust cybersecurity measures, including:

a. Mandate adherence to the International Maritime Organization's (IMO's) Guidelines on Maritime Cyber Risk Management.

b. Establish frameworks for identifying vulnerabilities, responding to incidents, and ensuring resilience against cyberattacks.

c. Require regular audits and certifications for cybersecurity readiness.

3. Insurance and Liability Provisions[40]

The insurance landscape for autonomous vessels must evolve to address unique operational risks, cyber threats, and environmental responsibilities. It should include:

I. Comprehensive Autonomous Vessel Liability Insurance

a. Coverage:

i. Third-party claims for collisions, cargo damage, and pollution.

ii. Losses from cyber-attacks, data breaches, or system failures.

iii. Additional coverage for eco-friendly vessels equipped with alternative fuel systems and energy-efficient designs.

b. Incentives:

i. Reduced premiums for shipowners implementing certified green and cybersecurity measures.

ii. Rewards for maintaining operational and cyber safety standards.

c. Penalties:

i. Additional charges for failing to meet safety, environmental, and cybersecurity standards.

ii. Increased deductibles or premiums for negligence-related claims.

II. Cybersecurity[41] and Environmental Compliance Insurance

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[39] Cyber risks

[40] Insurance & Liability

[41] Cybersecurity

a. Coverage:
   i. Costs for forensic investigations, legal fees, and system restoration.
   ii. Fines imposed for breaches of environmental or cybersecurity regulations, where legally insurable.
b. Incentives:
   i. Premium credits for vessels undergoing regular audits.
   ii. Financial support for upgrading to advanced technologies.
c. Penalties:
   i. Coverage Limit Reductions: For non-compliance with recommended cybersecurity measures.
   ii. Exclusions for incidents arising from known but unaddressed vulnerabilities.

III. Performance-Based Green Shipping Insurance

a. Coverage:
   i. Protection against disruptions, inefficiencies, and system failures.
   ii. Coverage for liabilities from oil spills, emissions, or waste disposal.
b. Incentives:
   i. Rebates for superior operational efficiency and environmental performance.
   ii. Discounts for ships holding recognized eco-certifications.
c. Penalties:
   i. Premium increases for poor performance or environmental incidents.
   ii. Required implementation of improvements after claims, with non-compliance leading to policy cancellations.

4. Incentivizing Technological Development
   a. Facilitate collaborations between government bodies and private enterprises to drive R&D.
   b. Provide tax benefits for investments in autonomous technologies.
   c. Create funds akin to the Maritime Development Fund proposed under the Sagarmala[42] Initiative to support research and deployment of autonomous solutions.
   d. Incentivize the adoption of eco-friendly innovations through grants, rebates, and reduced regulatory fees.

5. Aligning with Sustainable Development Goals (SDGs)
   a. Encourage the use of alternative fuels and energy-efficient systems to meet global emission targets.
   b. Strengthen liability provisions for environmental damage caused by autonomous vessels.
   c. Support the development of a robust autonomous shipping sector to enhance India's maritime competitiveness.

6. Other Recommendations:
   a. Update the Carriage of Goods by Sea Act, 1925 to include obligations related to digital documentation, automated systems, and advanced cargo handling technologies.
   b. Revise liability limits to reflect the realities of high-value shipments and modern risks, ensuring fair compensation for cargo damage or delays.

[42] Sagarmala

c. Harmonize the Act with international standards such as the Hague-Visby or Rotterdam Rules to address electronic bills of lading, containerization, and multimodal transportation effectively.

d. Establish more robust mechanisms for dispute resolution, including incorporating arbitration and mediation provisions suited for international maritime trade.

e. Strengthen provisions to improve first-mile and last-mile connectivity in India, ensuring seamless integration of domestic transport modes with global supply chains.

f. Establish oversight mechanisms to ensure that pricing and operational autonomy do not result in unhealthy competition or monopolistic practices among ports.

g. Define the Board's jurisdiction, roles, and coordination with other authorities to avoid regulatory overlaps and enhance dispute resolution efficiency.

h. Introduce comprehensive guidelines for identifying stressed PPP projects, restructuring contracts, and attracting fresh investments.

i. Implement a robust framework for market-driven pricing that ensures transparency and safeguards the interests of smaller stakeholders.

j. Incorporate provisions for environmental management and sustainable development, aligning port operations with global green port standards.

B. Collaboration with International Regulatory Bodies

1. Participation in IMO's MASS Code Development:

India must actively contribute to the IMO's Maritime Autonomous Surface Ship (MASS) Code[43]. This will help shape global rules while ensuring they address India's specific needs.

2. Strengthening Regional Maritime Cooperation:

Collaborate with Bay of Bengal states and Quad nations to harmonize autonomous shipping regulations and establish shared frameworks for information sharing, training, and technology transfer.

3. Flag State and Port State Control:

a. Ensure that autonomous ships operating in Indian waters comply with IMO conventions like SOLAS and MARPOL.

b. Adopt a leadership role in setting compliance standards for MASS in the Indian Ocean Region (IOR), leveraging India's strategic location.

4. Stakeholder Engagement:

a. Work with classification societies, shipowners, and insurers to address regulatory gaps and align with global standards.

b. Encourage initiatives like the Unified Logistics Interface Platform (ULIP) to integrate data-sharing mechanisms for autonomous systems.

C. Roadmap for Developing a National Autonomous Shipping Strategy

Phase 1: Foundation and Infrastructure Development (0–3 Years)

1. Institutional Framework Establishment

[43] MASS Code

a. Form a dedicated national Autonomous Shipping Task Force under the Ministry of Ports, Shipping and Waterways (MoPSW) to coordinate the development of policies, regulations, and industry standards.
b. Set up a steering committee comprising stakeholders from government agencies, research institutions, shipping companies, and tech firms to monitor and guide implementation.

2. Research and Development (R&D) Focus
   a. Invest in R&D for autonomous vessel technologies, focusing on navigation systems, AI, machine learning, sensor integration, and cybersecurity.
   b. Collaborate with Indian Institutes of Technology (IITs), Indian Space Research Organisation (ISRO), and other research bodies to enhance indigenous capabilities.

3. Pilot Projects and Testbed Creation
   a. Launch pilot projects for autonomous vessels in controlled areas with limited commercial traffic, such as ports or certain stretches of the coastline (e.g., JNPT, Mumbai Port, Chennai Port).
   b. Develop test corridors to assess the performance of autonomous ships under real-world conditions.

Phase 2: Regulatory Framework and Legal Infrastructure (3–5 Years)

1. Establish Regulatory Standards
   a. Draft national regulations for Maritime Autonomous Surface Ships (MASS), in alignment with International Maritime Organization (IMO) guidelines, while adapting them to local conditions.
   b. Address key areas such as liability, data sharing, cybersecurity, insurance, and vessel certification.
   c. Ensure compliance with International Safety Management (ISM) Code and International Convention for the Safety of Life at Sea (SOLAS).
2. Cybersecurity and Risk Management
   a. Implement cybersecurity protocols for autonomous systems to prevent cyber threats, given the high reliance on AI and IoT technologies.
   b. Form collaborations with cybersecurity firms to develop specialized solutions for maritime cybersecurity challenges.
3. International Collaboration and Standards Setting
   Actively participate in international maritime forums such as the IMO and Regional Cooperation agreements to contribute to the establishment of global standards for autonomous shipping.

Phase 3: Ecosystem Building and Industry Collaboration (5–10 Years)

1. Public-Private Partnerships (PPP) and Industry Development
   a. Establish Public-Private Partnerships (PPP) to promote joint ventures between domestic maritime companies, technology providers, and research institutions.
   b. Offer incentives, tax breaks, and grants for shipping companies to adopt and invest in autonomous technologies.
   c. Engage with Indian shipbuilders to create a domestic fleet of autonomous vessels.
2. Workforce Training and Skills Development
   a. Launch training programs and certification courses for maritime professionals to acquire skills in autonomous ship operation, cybersecurity, and vessel maintenance.

b. Collaborate with maritime academies, universities, and private training institutes to offer specialized courses.

3. Smart Ports and Digital Infrastructure
   a. Upgrade port infrastructure to accommodate autonomous vessels, including smart ports, enhanced communication networks, and port automation systems for seamless integration.
   b. Invest in 5G networks, satellite-based navigation, and AI-powered logistics for enhanced coordination.

Phase 4: Commercial Deployment and Scaling (10–15 Years)

1. Full-Scale Commercial Operations
   a. Begin the commercial deployment of autonomous vessels on high-traffic routes and in international shipping.
   b. Integrate autonomous systems into India's Sagarmala Program, aimed at modernizing ports and logistics infrastructure.
2. International and Regional Expansion
   a. Expand India's role in international shipping, offering autonomous vessel services to other countries in the Indo-Pacific region.
   b. Explore opportunities for collaborations with Southeast Asia, Africa, and the Middle East for joint ventures and infrastructure development.
3. Continuous Technological Innovation
   a. Invest in continuous upgrades of autonomous technologies, including improvements in AI algorithms, battery efficiency, green shipping technologies, and autonomous port management systems.
   b. Develop next-generation autonomous ships with features such as zero-emissions and autonomous port-to-port navigation.

Phase 5: Long-Term Leadership and Global Influence (15+ Years)

1. Global Leadership in Maritime Autonomous Technology
   a. Position India as a global leader in the development and regulation of autonomous shipping, particularly in sustainability and digital maritime solutions.
   b. Promote India's expertise in autonomous shipping through international partnerships and participation in IMO working groups.
2. Sustainability and Environmental Impact
   a. Ensure that autonomous ships adhere to high environmental standards, including reduced emissions and minimal environmental disruption.
   b. Support green shipping initiatives that leverage renewable energy and electric vessels.

IX. Conclusion

The adoption of autonomous ships in India offers immense potential to transform its maritime sector, enhancing efficiency, safety, and sustainability. However, realizing this potential requires significant changes in India's maritime legal framework. Updating existing laws, incorporating cybersecurity measures, and establishing clear liability provisions are essential to address the complexities of autonomous operations. Furthermore, active participation in the development of international regulatory frameworks, like the IMO's MASS Code, and fostering collaboration with global and regional

partners will be critical. By investing in technology, R&D, and workforce development, India can leverage its strategic location and robust maritime ecosystem to emerge as a leader in autonomous maritime technology, fostering economic growth and enhancing its geopolitical influence in the Indian Ocean Region.

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