

ARTIFICIAL INTELLIGENCE AND MARINE ECONOMY DEVELOPMENT: INSIGHTS FROM PAKISTAN

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ABSTRACT

Oceans form the backbone of global trade and maritime security. However, governance failures and environmental degradation have impacted the sustainable development of oceans worldwide. Pakistan's marine economy also mirrors such global trends. Despite having a strategic maritime location, the contribution of the marine economy to Pakistan's GDP is limited. The Gross Marine Product accounts for only 0.34% of the country's total economy. This study addresses the primary research question of how Artificial Intelligence (AI) can help Pakistan in the development of its marine economy. It explores AI integration in Pakistan's marine economy. The study also explores Pakistan-specific AI and Marine economy constraints such as data gaps, inadequate institutional capacity, and financial limitations. Using a qualitative research design combining marine economy & AI literature and expert interviews, the study highlights key areas of impact, such as predictive maintenance, intelligent harvesting, disease detection, and GIS (Geographic Information System) based ecosystem monitoring. The study concludes that a phased-based integration of AI technologies is essential for maintaining workforce relevance, keeping technological pace with regional countries, and strengthening the national marine economy through improved sustainability and maritime domain awareness.

KEYWORDS: AI, Marine Economy Development, GIS, Gross Marine Product (GMP), Life Below Water, AI Governance.

INTRODUCTION

For centuries, oceans have served as the backbone of global economic activity, facilitating the bulk of international trade, supporting livelihoods, and sustaining maritime security. However, unsustainable extraction of oceanic resources and expanding industrial activities are creating ecological and socio-economic pressures and limiting countries' ability to harness their oceanic resources (Gesami, 2024). Pakistan's maritime sector also mirrors such global trends. Pakistan has a 1,046-kilometre coastline along with an extensive Exclusive Economic Zone (EEZ) covering 290,000 sq. km of the sea. More than 90 per cent of the country's international trade is conducted through Sea Lines of Communication

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(SLOCs). Decades of overexploitation of oceanic resources and weak ocean governance, however, have limited the development of Pakistan's marine economy³ as well as disrupted "life below water"⁴ (PBC, 2025). The Gross Marine Product (GMP) accounts for a meagre 0.34% of Pakistan's GDP (Figure 1) (Salman & Shah, 2024).

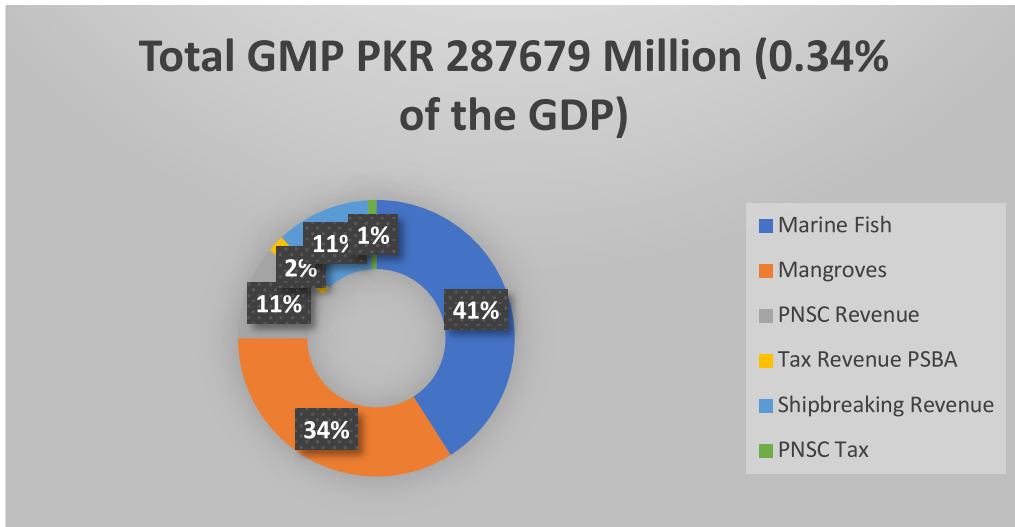


Figure 1: Gross Marine Product of Pakistan
Source: Salman & Shah (2024)

³ The Maritime Economy refers to sea-based activities related to ships, ports, and navigation. The Marine Economy refers to activities involving the extraction and utilisation of marine resources, including fisheries, offshore hydrocarbons etc. The Blue Economy, however, focuses on the sustainable use of oceanic resources. This study uses the Marine Economy definition as it focuses more on resource-oriented activities and their technological transformation through AI. The Maritime Economy is not sufficiently comprehensive for this purpose, as it is primarily confined to transport and logistics. The Blue Economy introduces a sustainability dimension that does not fully correspond to the scope of this study, given that not all AI applications in marine contexts are not sustainable.

⁴ This study adopts "Life Below Water" (inspired by the United Nations' SDG 14) as one of the guiding principles for marine economy development. SDG 14, among others, focuses on better ecosystem monitoring and preserving biodiversity to ensure sustainable resource use. By aligning with this objective, the research links AI adoption to ecological health, ensuring that the modernisation of Pakistan's marine economy is sustainable & ethically grounded.

Globally, AI (artificial intelligence) has emerged as a transformative technology for the development of the marine economy (Park, 2023). Developed economies have adopted AI across their maritime ecosystems and implemented it effectively. Pakistan has also signaled its commitment to modernising maritime infrastructure through various initiatives. Pakistan's NMP (National Maritime Policy) 2025 aims to reform sector governance and infrastructure. NMP 2025 proposes the formation/creation of the Pakistan Maritime and Sea Port Authority (PMSPA) to coordinate/oversee such reforms. The government's Uraan Pakistan initiative also aims to increase the maritime sector's contribution to GDP (from below 1% to 4% by 2047) (Government of Pakistan, 2026).

In 2025, Pakistan introduced its first National AI Policy (2025) with six pillars on governance, data and infrastructure, skills development, research and innovation, industrial adoption, and ethical AI. Multiple maritime and port-related projects under the CPEC (China-Pakistan Economic Corridor) have provided the infrastructure base needed for the marine economy's technological upgrading. Despite having such developments, the integration of AI into Pakistan's maritime sector is at an early stage. Limited attention has been given to how emerging technologies [such as AI and Machine Learning (ML)] can improve marine economy governance. There is a significant gap in the literature on the practical ways through which Pakistan can integrate AI into the development of its marine economy and solve its marine economy issues.

RESEARCH OBJECTIVES

This study makes an original contribution to the marine economy and AI literature by linking AI with the development of Pakistan's marine economy. It aims to improve "Life Below Water" through better management of the marine economy.

The objectives of the study are provided hereunder:

1. Identify key maritime areas where AI can augment traditional practices.
2. Explore the potential of AI to mitigate human-induced and natural climate-related risks in maritime.
3. Assess the institutional, infrastructural, and workforce-related challenges that may constrain the development of AI, particularly in Pakistan's marine economy.

LITERATURE REVIEW

This section critically assesses and synthesises the existing literature on AI and maritime development. The literature review suggests that traditional methods have failed to address the challenges facing the maritime sector. Such methods have been unable to solve maritime challenges (Yue, 2023; Zhang et al., 2024). The role of AI in the development of marine economies has received significant attention in recent years (Gesami, 2024). In fisheries and aquaculture, AI applications such as ML, computer vision, and predictive analytics have transformed global practices by enabling automated fish stock assessment, early disease detection, and precision feeding (Raza et al., 2022; Zhou et al., 2024). These technologies have improved efficiency and sustainability as well as reduced operational risks and labour costs (Batin, 2022; Park, 2023). AI-driven surveillance systems have improved regulatory compliance and combat illegal, unreported, and unregulated fishing in multiple maritime

zones (Ismail et al., 2023). In the maritime transport and ports sector, AI optimises route planning, navigational decision-making, and operational efficiency. Predictive maintenance models increase ship safety, reduce downtime, and lower lifecycle costs (Grieves & Vickers, 2017). Similarly, AI integration in naval and maritime defence improves domain awareness, route optimisation, risk forecasting, and response capabilities (Adeyemi & Jones, 2022). The literature, nonetheless, highlights the efficiency gains from AI adoption in maritime. Over the years, however, most studies conceptualise AI as a technical efficiency tool and evaluate outcomes within developed economies' contexts where data availability, regulatory coherence, and capital intensity are already assured.

METHODOLOGY

This study uses a qualitative research design. It combines an extensive review of peer-reviewed studies and reports from leading international organisations with detailed semi-structured in-depth interviews. The interviews were conducted using purposive sampling. The participants were selected based on their expertise in AI and Pakistan's regulatory environment. Given that AI integration in Pakistan's maritime sector remains at an early and underdeveloped stage, only three interviews were conducted. After the third interview, the responses reached theoretical saturation. For ethical reasons, participant identities have been anonymised. Further details about the interviews are provided in Table 1. In this study, maritime economy sectors were selected based on both literature review and expert insights. For production and livelihoods, fisheries and aquaculture were selected. For trade and logistics, the focus was given to ports and maritime transport. The remaining areas were maritime security and defence, environmental sustainability, climate and coastal ecosystems, and AI-related institutional and technological challenges.

Table 1: Interview Details

Participant Code	Institutional Type / Sector	Professional Role / Expertise	Years of Experience
Interview 1	Pakistan Navy	PhD in AI, expert in cyber security and Maritime affairs	+10 years
Interview 2	Pakistan Navy	Former Ambassador / Retired Vice Admiral	+20 Years
Interview 3	Academia	GIS and Maritime Researcher	+15 Years

RESULTS AND DISCUSSION

The results and themes highlighted after both the literature review and expert interviews are presented in Table 2. Based on thematic analysis, the table highlights that AI has the potential to improve efficiency across marine transportation, shipbuilding, fisheries, climate adaptation, and maritime security. The following sections discuss these themes in detail.

➤ MARINE TRANSPORTATION AND PORTS SECTOR

Pakistan's ports handle the majority of the country's external trade. Over 90% of international cargo is transported by sea lines of communications (SLOCs) through ports such as Karachi and Port Qasim (Salman and Shah, 2024). Experts stated that operational

inefficiencies, however, persist in Pakistan's ports (Interview 1; Interview 2; Interview 3). Average port cargo dwell time in Karachi is around 7 days compared with 2 days in more developed regional ports (World Bank, 2023).

Table 2: Themes Highlighted After Sectoral Analysis

Thematic Areas	Key Insights from Literature	Insights from Expert Interviews
Marine Transportation and Ports	AI improves route optimisation, fuel efficiency, port operations, and logistics performance.	Experts highlighted route planning, safety systems, port efficiency, and selective AI adoption
Shipbuilding and Naval Ship Management	Predictive maintenance, automation, and smart ship systems reduce lifecycle costs and downtime	Interviews emphasised sensors, predictive maintenance, robotics, and digitalisation gaps
Fisheries and Aquaculture	AI enables stock assessment, species identification, disease detection, and sustainable harvesting	Experts noted inefficiencies in manual surveys, bycatch issues, and disease losses
Fisheries Monitoring and Enforcement	AI-based surveillance strengthens IUU fishing control and stock governance	Interviewees stressed limits of manual monitoring and patrol capacity
Climate Change and Coastal Environment	AI and GIS support climate risk prediction, ecosystem monitoring, and adaptation planning	Experts highlighted fragmented monitoring and weak early-warning capacity
AI-GIS Integration	Spatial context improves AI accuracy in maritime and coastal systems	Interviews stressed reliance on satellite data and GIS due to data scarcity
Maritime Defence and Security	AI improves maritime domain awareness and surveillance	Experts emphasised drones, EEZ monitoring, and SLOC security
Institutional and AI Readiness Constraints	Data gaps, weak governance, limited human capital constrain AI adoption	Interviews confirmed institutional fragmentation and capacity gaps

Source: Author's based on the interviews and the literature

The application of AI in maritime can significantly improve navigational planning in Pakistan. By enabling dynamic route optimisation, predictive risk assessment, and real-time decision-making, AI can improve both the safety and efficiency of our merchandise trade (Interview 1). AI (with the help of historical data of the vessels and maritime transport and logistics) can transform such route planning and navigational decision-making. It can generate more optimised routes that reduce transit time and lower fuel consumption. Since the majority of Pakistan's international trade is transported by foreign carriers, Pakistan

also has the potential to generate economic value by providing auxiliary and value-added services such as AI-driven route optimisation, scheduling, and efficiency tools to international carriers transiting regional sea lanes.

➤ **SHIPBREAKING**

Pakistan's shipbreaking, shipbuilding, and recycling industry plays a crucial role in Pakistan's economy. The third largest contributor to the GMP of Pakistan (see Figure 1). The industry also generates around PKR 5 billion annually in tax revenues, as well as supporting the livelihoods of over 125,000 people (PBC, 2025). However, due to a lack of safety systems, multiple workers have died at the Gadani ship-breaking yard as a result of explosions, fires, and exposure to hazardous materials (Dejwani, 2025). The use of robotics and automation can improve precision and quality, as well as improve the safety and efficiency in the activities related to the construction, breaking, operation, and maintenance of ships, systems, and equipment at the Gadani Ship Breaking yard (Interview 1). "The issue is that large ships arriving for dismantling in Gadani often contain hazardous toxic materials, unstable metal structures, and heavy machinery, which frequently cause explosions, suffocation, fires, and fatal accidents for our workers" (Interview, 2). Robotics and automation can be introduced in hazardous material detection, gas monitoring, controlled cutting, and heavy lifting stages to minimise risk through minimal human exposure.

➤ **AI-ENABLED PREDICTIVE MAINTENANCE AND SMART SHIP OPERATIONS**

In Pakistan's ports, equipment failure often interrupts trade as well as results in significant trade losses (Interview, 2). AI-based predictive maintenance and fault detection can help address such issues (Interview 1). In Pakistan, another issue is that traffic density, operational stress, and maritime maintenance costs are comparatively high. The average turnaround/delay time of ships at Karachi is around 6 days. However, globally, it is closer to 2 days. AI can reduce such unplanned downtime and lower trade costs through its predictive maintenance systems (Interview 2).

➤ **AI IN MARITIME DEFENCE AND SECURITY FRAMEWORKS**

Pakistan's maritime geography places it in immediate proximity to critical regional shipping routes such as the Strait of Hormuz. Maritime activity is connected to national security. The safeguarding of Sea Lines of Communication (SLOCs) is an integral part of national security. The application of AI in maritime defence is centred around surveillance and the mitigation of traditional and non-traditional security threats (Interview, 1; Salman, 2011). However, a robust Maritime Domain Awareness (MDA) is a significant challenge. An important resolution in this domain is the use of AI-driven UAS (unmanned aerial systems). They, when equipped with advanced ML, are capable of better monitoring of oceanic expanses. This is a capability that is of prime value for overseeing MPAs (Marine Protected Areas) and enforcing regulations in remote/logistically remote maritime zones (Interview 1; Shi, 2021). Furthermore, through the analysis of large-scale vessel traffic data, AI systems can forecast shipping behaviour, analyse route dependencies, and identify vulnerabilities within SLOCs. International shipping routes, moreover cross/or border Pakistan's EEZs (Interview, 2). By identifying infrequent movement patterns, abnormal

speeds/behavioural anomalies, AI-integrated systems [such as those linked to the Joint Maritime Information Coordination Centre (JMICC)] can highlight vessels potentially involved in piracy/smuggling (or other illicit activities) (Interview, 1).

➤ FISHERIES AND AQUACULTURE

In fisheries and aquaculture, Pakistan follows traditional management practices such as manual stock assessments, disintegrated record-keeping, and often subjective decision-making processes based on old trawling methodologies that are manual or semi-automated (Zhang, 2024; FAO, 2022). Pakistan's reported post-harvest losses of above 20% are the result of such old maritime methods, among others. Grieves (2017) states that, for maximising economic benefits in fisheries, modern technology-based intelligent fisheries and aquaculture systems are important since they guarantee resource sustainability. Integration of AI-driven systems into harvesting operations could result in better resource usage. Globally, AI-based technologies (particularly computer vision and ML) are being installed for better management of fisheries. For example, in Norway, AI-enabled underwater camera systems integrated with ML algorithms are used in salmon farming to track fish behaviour and health conditions. However, for Pakistan, where management systems are manual (as stated), such technologies can be introduced in a gradual and context-sensitive manner (Interview, 1). Initial use in the country can focus on high-value aquaculture clusters and regulated trawl fisheries, where returns justify costs and institutional coordination is relatively stronger. The unintentional capture of non-target species (bycatch) is also a significant issue across multiple coastal regions of Pakistan. AI can play a role in addressing this issue through predictive analytics (Interview, 1). By analysing historical fishing data, oceanographic conditions, and species distribution patterns, ML models can help fishermen to stay away from areas with high concentrations of non-target species (Yue, 2023).

Along with Pakistan's trawl fisheries of Sindh and Balochistan, regulatory authorities have introduced onboard camera systems at particular points. However, the operational impact of such systems is limited by the dependency on manual footage review (Interview, 2). To overcome such challenges, Pakistan needs to integrate its digital technologies with AI-based decision-support systems to turn raw visual data into meaningful information. Using AI computer vision for real-time observation reading can help in attaining this objective (Yue, 2023). Identification and monitoring of multiple fish populations are important for better fisheries management. AI algorithms that are fine-tuned for detection, classification, and segmentation within marine environments can make better observations than manual surveys can match.

Moreover, in Pakistan, the task of determining fish age is also a significant issue (Interview, 2). However, ML techniques for sex determination, using morphometric ratios, provide an alternative to physical examinations, aligning with modern animal welfare standards in aquaculture and conservation (Barulin, 2019; Yang et al., 2021). AI-based machine vision can facilitate automated, real-time species identification and biomass estimation within the net. This will improve both the economic selectivity (targeting high-price species) and ecological selectivity (minimising bycatch), improving the market rate of the catch (Interview, 1). However, in Pakistan, the capital-intensiveness of such systems may act as a barrier to sector-wide AI implementation in fisheries and aquaculture, given that there

exist credit constraints and low investment capacity within Pakistan's the sector. Pakistan needs priority-based implementation

➤ **SELF-FEEDING SYSTEMS USING INTELLIGENT HARDWARE**

Within Pakistan's saline aquaculture sector, feed management/overfeeding is also one of the most critical issues. Often comprising 65% of total operational expenditure (Raza, 2023). However, there are significant inefficiencies (Interview, 2; Interview, 3). AI-driven automated feeding systems, widespread in ecologically modernised aquaculture zones globally, can overcome this challenge through the integration of sensing hardware and control logic. These AI systems synthesise data on key environmental variables and real-time fish feeding behaviour (e.g., surface activity analysis via computer vision), dynamically modulating feed dispersion rates in response to actual biological demand. When critical water quality parameters (such as dissolved oxygen) lapse pre-defined biological safety thresholds, the AI systems are programmed to trigger automatic mitigation measures. They, for instance, suspend feeding and alert human operators when a certain level of feeding is reached. In Pakistan, even alerting humans through alarms can play an important role where feeding systems lack control and monitoring mechanisms (Interview, 3).

The effective placement of such technologies, however, may depend upon the existence of localised technical expertise required for their operation and maintenance. In Pakistan, initial rollout may be concentrated in established aquaculture clusters where infrastructure, market access, and commercial fish farming are already happening. Financing is an important factor to consider as well. Large commercial farms and corporate investors who can absorb the upfront costs, supported by targeted government subsidies, concessional credit schemes, and tax rebates tied to performance, should move first. Over time, as unit costs decline with technological maturation, the model should be extended at scale across the rest of the areas (Interview, 2). Commercial parts of Sindh and Balochistan, such as Thatta, Hub, and Badin, can be used as a pilot for such AI experiments. A significant catalyst that needs to be taken into consideration for AI transformation is the CPEC 2.0 "Digital Corridor" and its maritime infrastructure investments. Modern logistics hubs at Gwadar provide the necessary "backbone" for cloud-based AI processing and real-time data transmission from sea to shore. However, in the implementation phase, priority may be given to sectors having a higher ROI probability to reduce input costs. The digitalisation of Pakistan's marine economy may be viewed as an evolutionary process. By introducing advanced AI capabilities through phased implementations, the country can modernise its fisheries sector in a way that meets local economic limits as well as international competitive standards and fulfills the objectives of its national maritime and digital policies (Interview 1; Interview 2; Interview 3).

➤ **AI IN CLIMATE CHANGE AND ENVIRONMENT**

Pakistan's coastal and marine ecosystems are also exposed to climate-induced pressures such as salinity intrusion (as discussed), rising sea-surface/temperatures, coastal erosion, and water pollution. and ecosystem degradation. The issue is that Pakistan uses traditional systems that rely on visual cues, such as changes in water color, to assess water quality and its impacts. In the country, the focus is more on the overexploitation of resources and less on sustainability (Dejwani, 2025). In areas such as Thatta, Badin, and

Keti Bandar, water quality is often not monitored. Periodic sampling occurs. However, it is largely manual in carp polyculture systems and shrimp farms located in the Indus Delta (Salman, 2010). Such traditional types of monitoring often fail to detect timely water quality deterioration, leading to significant production losses (Interview 3).

➤ **CLIMATE CHANGE, AI, AND GIS (GEOGRAPHICAL INFORMATION SYSTEM)**

AI-integrated GIS systems using high-resolution satellite imagery can track changes in coral reefs and seagrass beds, as well as better address the environmental challenges that Pakistan is grappling with (Interview 3). Pakistan already has satellite coverage and data of the Arabian Sea, Indus Delta, and vulnerable coastal districts of Sindh and Balochistan (Interview, 3). It can use this data through AI-enabled geospatial systems for coastal risk forecasting. Deep-learning models (such as FloodNet) and related AI-based flood mapping frameworks show that satellite imagery, terrain models, and hydrological inputs can be integrated for real-time risk assessment. However, in Pakistan, AI adoption for climate resilience is at an early stage. The availability of satellite data, climate records, and hydrological information provides a foundation for integrating AI-based forecasting and monitoring into coastal and marine planning.

HOW CAN AI AND GIS BE COMBINED IN MARITIME APPLICATIONS?

In the maritime sector, GIS can function as a mapping/visualisation tool. GIS can act as the spatial backbone on which AI-driven models can be built (Interview, 3). Multiple AI applications in fisheries management, port optimisation, climate risk assessment, and maritime security require location-specific details. GIS provides this by putting spatial data on sea surface temperature, bathymetry, shipping lanes, fishing grounds, mangrove ecosystems, coastal infrastructure, and ecological zones into interoperable layers. In Pakistan's case, the role of GIS in AI-enabled maritime development is particularly critical (as stated) because primary data availability is limited (Interview, 3). Most datasets relevant to fisheries, climate, and coastal management are satellite-derived and spatial in nature. GIS, therefore, becomes the mechanism through which multiple datasets can be harmonised and fed into Pakistan's AI systems. This implies that, for Pakistan, investment in AI for maritime development may be preceded by or at least parallel to the development of integrated GIS-based data systems that consolidate environmental, economic, and operational information at the coastal and marine scale.

For GIS to be of significance, however, it may be understood within the specific national context/circumstances of Pakistan. AI systems do not operate effectively on isolated variables/narrowly defined datasets. Their analytical strength lies in the integration of data-rich, multi-temporal, multi-source, and multi-dimensional information. Without such integration, AI-driven outputs are likely to remain generic and of limited policy relevance. Expanding existing maritime networks through GIS-based installations and dedicated AI sensors involves prohibitive capital costs. In the short to medium term, it is therefore more feasible to utilise existing dual-use infrastructure, such as the Joint Maritime Information Coordination Centre's (JMICC) radar and satellite feeds, the CPEC-linked fiber-optic backbone along the Makran Coastal Highway, and SUPARCO's established geospatial imaging platforms. By layering AI-based analytical modules over these functional assets, Pakistan can achieve advanced maritime domain awareness and resource monitoring without the immediate need for a complete overhaul of its physical hardware (Interview, 3).

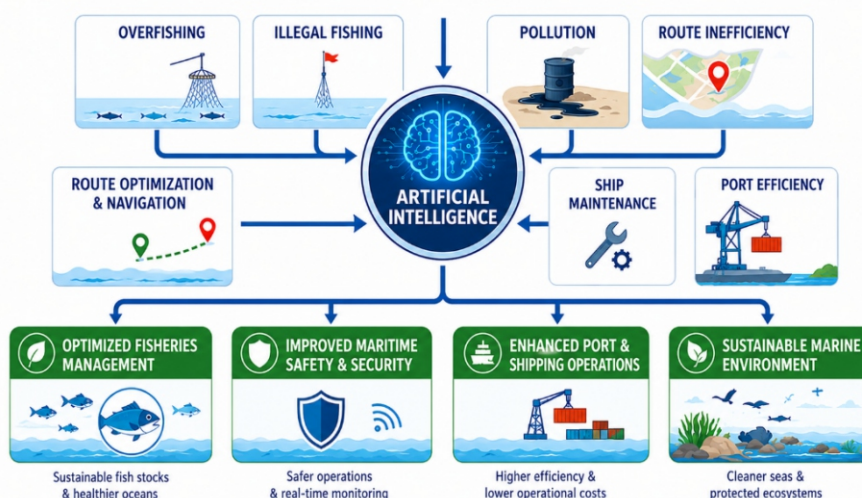


Figure 2: AI based Maritime Development
Source: Author's based on the literature

Another alternative approach is to rely on existing global remote sensing and GIS products to support decision-making. This approach reduces financial costs. Overall, the AI-based maritime development for Pakistan is summarised in Figure 2.

PAKISTAN'S AI LANDSCAPE, CHALLENGES AND WAY FORWARD

Pakistan's National AI Policy identifies human capital, data, infrastructure, governance, and ethics as the prerequisites for meaningful AI adoption. This section explores Pakistan's AI landscape, the challenges to AI adoption, and provides a way forward for Pakistan.

Gartner (2025) argues that, in 2028, AI will become an essential component of the marine economy, making its integration necessary for getting jobs, workforce relevance, and productivity. However, Pakistan has an overall score of 45.38 on the AI Readiness Index. Places it in the lower-middle category of AI readiness (Oxford, 2025). Globally, Pakistan's ranking is 81, far below the global average. Research & development capacity of Pakistan in maritime-related fields is limited as well. Pakistanis rely on foreign maritime consultants and classification societies. This dependence limits our ability to develop indigenous AI models. Models that may align with local operational environmental and regulatory conditions (Mehmood, 2026). Institutional capacity, moreover, acts as a constraint in AI. Ministries/regulatory bodies dealing with the marine economy often lack technical expertise and continuity.

Policies are often not based on rigorous analysis. This problem becomes more severe when engaging with complex technologies such as AI or blockchain. Here, a misunderstanding of operational requirements leads to poorly designed initiatives. Disintegrated policymaking, lack of implementation, and limited coordination across institutions have, over the years, weakened the effectiveness of multiple technological interventions like AI (Salman & Shah, 2024; Interview, 3). In Pakistan, federal-provincial miscoordination acts as an additional layer of complexity. The devolution of fisheries under the 18th Amendment has resulted in jurisdictional disputes (as well as between Sindh and Balochistan). Coastal regions of Sindh and Balochistan are among the least developed parts of the country, characterised by aridity, poverty, weak infrastructure, and multiple security/development challenges. Except for a small number of ports, maritime infrastructure is negligible. Governance deficiencies and weak accountability mechanisms further reduce the returns of marine economic activities (or ROI). Core maritime institutions show misalignment. The maritime ministry is often headed by non-maritime experts (individuals from Pakistan's administrative services, or PAS) who often lack maritime knowledge. Such arrangements decrease the probability of improving efficiency, innovation, and technological upgrades (Interview, 2). Private-sector exclusion is also one of the most critical areas of concern in Pakistan. Globally, maritime industries are driven by the private sector/firms.

The state acts as a regulator and facilitator. In Pakistan, state dominance in commercial maritime operations has resulted in bureaucratic inertia. Maritime corporations such as the PNSC operate under guaranteed cargo and rates. This reduces competitive pressure and result in inefficient pricing/rates, leaving little incentive to innovate, optimise operations, or adopt modern AI-based solutions. Given Pakistan's weak fiscal condition and low investment in the marine economy, AI adoption may still be limited without the private sector (Interview, 2). The adoption of AI in maritime defence also has significant potential. AI raises ethical, legal, and security concerns, however. The data used in maritime surveillance often includes sensitive commercial, personal/national security information. Risks such as cyberattacks, data manipulation, misinformation, and infrastructure fragility present significant challenges. These risks demand robust ethical guidelines, cybersecurity protocols, and legal frameworks to ensure that AI deployment does not compromise national security and, more importantly, civil liberties (Interview, 2). Capacity-building (as stated) and human resource development in AI and GIS are also challenges. Through GIS- and AI-focused courses, workshops, and short training programs, a more skilled human resource can be formed. Some universities already offer AI-related degrees and training in

Pakistan. In the short run, existing curricula can be used to incorporate marine and coastal applications. Building comprehensive systems at once may be difficult in a developing country like Pakistan. A phased, component-based approach using existing resources may allow for learning, adaptation, and gradual AI exploitation (Interview, 3).

A recurring theme throughout the study is the cost associated with AI, as AI-driven optimisation significantly increases cost. This highlights one of the most important issues, which is whether Pakistan may pursue maximum AI adoption in the maritime sector (particularly in the short run), given that the country also has a very low overall score for AI Readiness. Given Pakistan's limited commercial fleet and constrained fiscal space, an abrupt, full-scale implementation of AI in the marine economy may not yield significant short-term economic returns. However, over the years, historical evidence shows that technological stagnation (such as digitalization before the COVID era) created significant challenges. In 2020, during COVID times, regional competitors were taking advantage of their advanced digital technologies. However, Pakistan was grappling with internet connectivity issues due to its passive approach. As a result, regional technological asymmetries rose. In AI, the appropriate response, therefore, is neither to reject AI nor to adopt it abruptly but to remain competitive in the region (Interview 1).

COUNTER-RISK PERSPECTIVES ON AI

An ample amount of literature suggests that AI also has risks. High investment costs, workforce displacement, and dependence on foreign technology providers are the major issues. Ignoring these risks could lead to overoptimistic policies that may not be feasible under Pakistan's socioeconomic/fiscal constraints (Interview, 2). The national AI Policy (2025) moreover highlights that ethical and social implications should be central to any discussion on AI. AI-driven automation, however, disproportionately affects small-scale fishers and vulnerable coastal communities who lack the resources to move to AI. Therefore, equity and access concerns are also important. Moreover, another issue is that AI benefits often accrue to larger/wealthier enterprises, since they have more capital to invest in advanced technologies. AI could increase existing inequalities in Pakistan (particularly in its developing coastal regions such as Balochistan). Inclusive financial models and public-private partnerships can overcome such issues and may help spread the benefits of AI to small-scale/artisanal fishers (FAO, 2021).

AI also raises concerns about the erosion of cognitive skills, traditional knowledge, and cultural heritage. Overreliance on AI tools can weaken human analytical capacity and judgment. Multiple organisations restrict the use of autonomous AI. AI can address such concerns. In Pakistan, for coastal communities, fishing is a cultural practice. Ethical AI implementation may, however, integrate traditional knowledge. Co-management approaches, in which fishers actively participate in the design and deployment of AI systems, offer a viable pathway to balance innovation with cultural preservation (Interview, 3). Opponents/critics of AI often portray AI as both a disruptive and destructive technology. They argue that it may destabilise labour markets, displace workers, and lead to unemployment. However, it is important to recognise that, as with earlier technological innovations [the internet (the dot-com bubble) and calculators], AI has the potential to improve productivity. Technologies that are heavily invested in by global giants/developed

economies have significantly improved efficiency over the years by saving time and resources. AI is more likely to complement labour and generate new employment opportunities by augmenting human decision-making and operational efficiency (Interview 1). However, transition costs are real and may be addressed through reskilling/up-skilling and social protection measures (Interview, 1; Interview, 2; Interview, 3).

CONCLUSION

This study explored the role of AI in Pakistan's maritime development. The analysis shows that AI holds significant potential across multiple sectors. The study also identified major Pakistan-specific constraints, including fragmented data systems, institutional limitations, lack of skilled human capital, limited R&D, governance gaps, and the government's fiscal constraints. The study further argued that AI is particularly important for Pakistan, where inefficiencies across maritime logistics, fisheries, environmental monitoring, and port operations are significant. Much like earlier technological shifts such as the internet and calculators, AI will not replace human labour but augment it by improving decision-making, operational efficiency, and productivity. However, AI adoption in Pakistan's marine economy may not be treated as a technological upgrade.

Issues such as weak provincial-federal coordination, low private sector participation, cybersecurity risks, and unequal access to finance and digital infrastructure may first need to be addressed. Such barriers are more significant for small-scale fishermen and coastal communities of Balochistan and Sindh. Regular evaluation reports, stakeholder engagement, and efficient AI governance frameworks are needed for better technological adoption and higher productivity. This will also ensure resilience without growing existing socioeconomic inequalities. Such weaknesses have historically slowed the implementation of other technologies in Pakistan. The study, in essence, concludes that integrating AI within our national maritime and digital systems can help Pakistan align technological modernisation with sovereign maritime objectives as well as strengthen food security, improve environmental sustainability, and support "Life Below Water," the long-term development of the country's marine economy.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author(s).

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