Leveraging Emerging Technologies to Enhance Business Processes in Blue Economy Sectors: A Case Study of Anambra State's Industrial Landscape

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Abstract

This study examined how emerging technologies improve business processes within Anambra State's blue economy sectors, with emphasis on aquaculture, fisheries, and inland water transport. It aimed to identify relevant technologies, assess their level of application, evaluate their operational effects, and determine the barriers limiting wider uptake. The study adopted a systematic review design grounded in thematic analysis and guided by Saunders' Research Onion and PRISMA procedures. Literature was drawn from Scopus, Google Scholar, and Web of Science, using studies published from 2014 to 2024. The findings show that artificial intelligence, blockchain, big data analytics, and the Internet of Things improve process visibility, monitoring, traceability, coordination, and decision quality across blue economy activities. In fisheries and aquaculture, digital tools support water quality monitoring, production oversight, and market linkage. In inland transport and logistics, they improve cargo tracking, documentation flow, communication, and operational control. These gains remain uneven because adoption is constrained by unstable power supply, weak internet access, high technology cost, limited finance, skill deficits, maintenance difficulty, cybersecurity concerns, and policy uncertainty. Sector comparison shows that fisheries and aquaculture remain at an early adoption stage, while inland water transport is in a transitional stage with partial digital reform. The study concludes that technology integration in Anambra State's blue economy depends on stronger infrastructure, targeted financing, workforce training, clear regulatory standards, and phased pilot implementation. It recommends coordinated action among government, industry, academia, and technology providers to improve adoption, strengthen sustainability, and support long-term process improvement.

Keywords: *Blue Economy; Business Process Optimization; Digital Transformation; Industry 4.0; Smart Manufacturing*

INTRODUCTION

The blue economy has emerged as a significant catalyst for sustainable economic growth, harnessing the wealth of our oceans, seas, and water bodies. Recent studies indicate that incorporating emerging technologies such as artificial intelligence (AI), blockchain, big data analytics, and the Internet of Things (IoT), can optimize business processes, enhance efficiency, and support sustainability within blue economy sectors (Bailey, 2022; Chidiebube *et al.*, 2025a; Onyeka and Emeka, 2025; Igbokwe and Nwamekwe, 2025a). Anambra State, Nigeria, exemplifies a promising landscape for this exploration, given its rapidly evolving industrial framework. In analysing the integration of these technologies, it becomes evident that not only are operational efficiencies heightened, but they also foster an adaptive ecosystem that aligns industry practices with environmental stewardship (Zhang *et al.*, 2024; Igbokwe *et al.*, 2025c). The synergy between emerging technologies and the blue economy offers transformative potential, paving the way for Anambra State to emerge as a leader in sustainable industrial practices while reaping the multifaceted benefits of an increasingly interconnected global economy (Hassan *et al.*, 2018; Ezeanyim *et al.*, 2025a; Nwamekwe *et al.*, 2025a).

Despite the promising potential of emerging technologies to transform business processes, the blue economy sectors in Anambra State continue to face significant challenges related

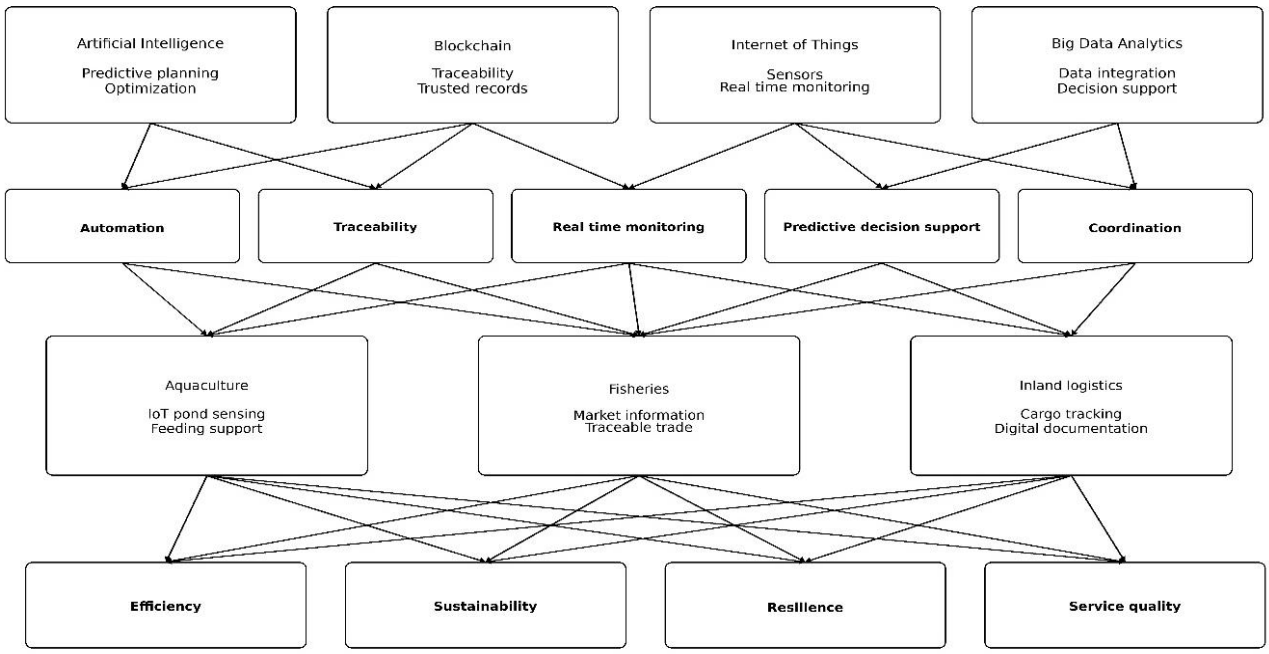

Fig. 1: Conceptual framework linking emerging technologies to business process outcomes in blue economy sectors.

to technological integration. Industries within this region remain largely underdeveloped, primarily due to inefficient operational processes, limited technological adoption, and inadequate access to essential digital tools (Parviainen *et al.*, 2022; Onyeka et al 2024; Nwamekwe *et al.*, 2020). The lack of digital infrastructure hampers these industries from reaping the benefits of technologies like AI, blockchain, and IoT, which are crucial for enhancing operational efficiency and supporting sustainable practices (Nwamekwe *et al.*, 2024a; Vitalis *et al.*, 2024). There is a pressing need to understand how these emerging technologies can be strategically leveraged to overcome existing barriers, thereby contributing to economic sustainability and resilience in Anambra State's industrial landscape (Okeagu *et al.*, 2024; Emeka *et al.*, 2025). Addressing these challenges through a focused exploration of technology adoption is essential for enabling growth and development within the blue economy sectors, highlighting the urgency for both research and practical implementation in this context.

This study aims to explore how emerging technologies can enhance business processes within the blue economy sectors of Anambra State, providing insights into their adoption, impact, and challenges. The research objectives include identifying key emerging technologies relevant to business process optimization, assessing their implementation in various blue economy industries, evaluating their effectiveness in improving operational efficiency, and examining the challenges hindering their widespread adoption. The study also aims to propose strategic recommendations for policymakers and industry stakeholders to foster technology-driven growth in these sectors (Nwamekwe and Nwabunwanne, 2025). The scope of this research encompasses industrial activities within Anambra State's blue economy, focusing on industries such as aquaculture, fisheries, maritime logistics, and related sectors, while analysing recent advancements from 2014 to 2024.

Fig. 1 consolidates the research's full analytical logic into a single visual pathway. It positions Artificial Intelligence, blockchain, Internet of Things, and big data analytics as the enabling technologies, links them to the process mechanisms identified in the text, and then connects these to sector applications in aquaculture, fisheries, and inland logistics before ending with the stated business outcomes of efficiency, sustainability, resilience, and service quality.

METHODOLOGY

Research Design

This study adopts a systematic review approach grounded in thematic analysis, integrating Saunders' Research Onion Model to ensure methodological rigor across various layers of research design. The model provides a structured framework guiding the research through key stages, including research philosophy, approach, strategy, choices, time horizon, and techniques (Saunders *et al.*, 2019). At the philosophical level, the study aligns with an interpretivist paradigm, emphasizing the exploration of themes and patterns from existing literature rather than empirical data collection. The research approach follows an inductive path, enabling a deeper understanding of how emerging technologies enhance business processes in blue economy sectors (Ezeanyim *et al.*, 2025b; Chidiebube *et al.*, 2025b; Okpala *et al.*, 2024a; Igbokwe *et al.*, 2024a; Nwamekwe *et al.*, 2025h).

The strategy employed is a systematic literature review, ensuring a comprehensive synthesis of relevant studies. Following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework, the study maintains transparency, replicability, and methodological rigor in selecting and analysing literature

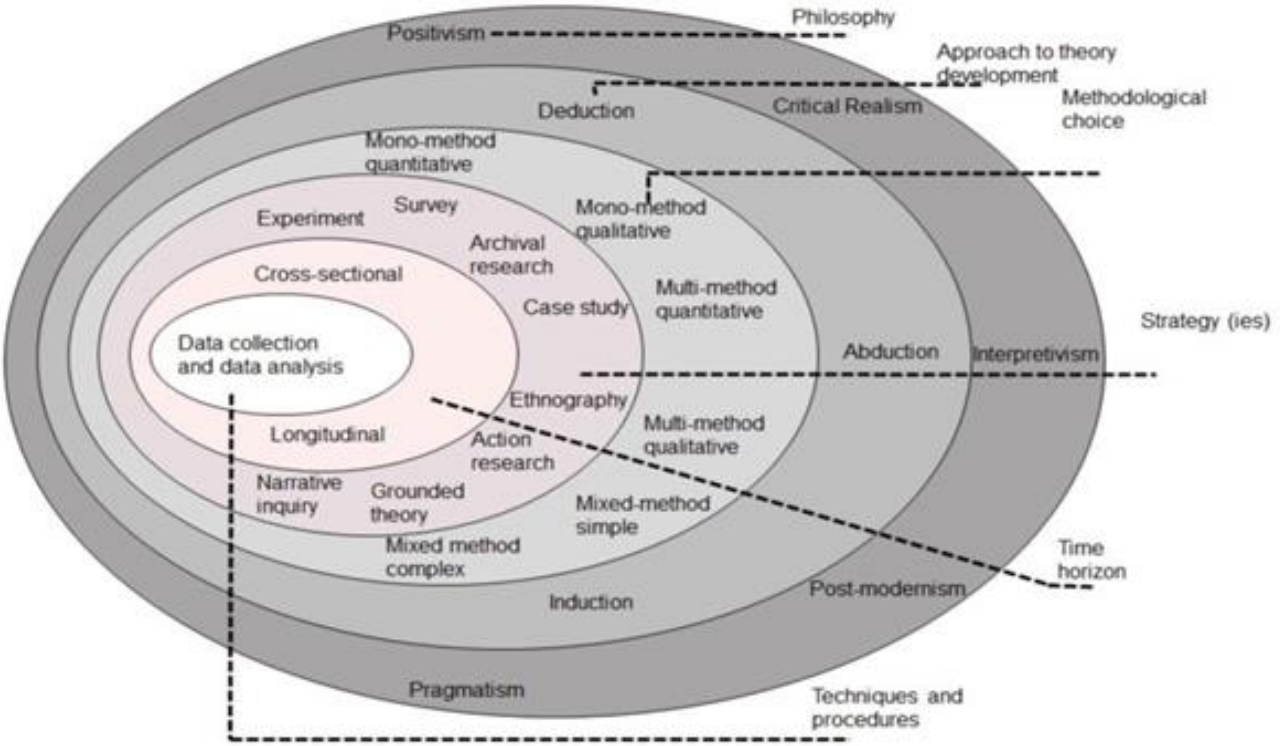

Fig. 2: Research onion (Saunders *et al.*, 2019).

(Nwamekwe *et al.*, 2025c). The research choices involve a mono-method qualitative approach, with thematic analysis as the core technique for extracting insights. A cross-sectional time horizon is adopted, focusing on studies published between 2014 and 2024 to capture recent advancements in digital innovations for blue economy industries.

As shown in Fig. 2, the systematic review design is particularly well-suited for identifying recurring patterns, technological applications, and policy implications across multiple studies. This approach helps pinpoint existing research gaps and provides insights that contribute to both theoretical and practical advancements in business process optimization through emerging technologies (Nwamekwe *et al.*, 2024b; Okpala *et al.*, 2025a; Chidiebube *et al.*, 2025c). By integrating Saunders' Research Onion Model within the systematic review framework, the study ensures a structured and rigorous methodological approach, enhancing the validity and depth of its findings.

Data Collection Methods

Data for this review were systematically collected (Fig. 3) from reputable academic databases, such as Scopus, Google Scholar, and Web of Science, ensuring access to high-quality, peer-reviewed literature. The selection of these databases was crucial due to their extensive coverage of scholarly publications, particularly in technology, business management, and industrial development (Nwamekwe *et al.*, 2025b). The search terms were carefully developed to capture relevant studies within the scope of this research. The Boolean search string employed was: ("Emerging Technologies" OR "Digital Technologies" OR "Industry 4.0" OR "Artificial Intelligence" OR "Blockchain" OR "IoT" OR "Big Data" OR "Automation" OR "Machine Learning") AND ("Business Process Optimization" OR "Process Efficiency" OR "Operational Efficiency" OR "Digital Transformation" OR "Business Process Management") AND ("Blue Economy" OR "Marine Economy" OR "Sustainable Fisheries" OR "Aquaculture" OR "Maritime Industry") AND ("Anambra State" OR "Nigeria" OR "Developing Economies").

To ensure the comprehensiveness of the review, filters were applied to include studies published between 2014 and 2024. This time frame was selected to reflect recent advancements in emerging technologies and their application in optimizing business processes within the blue economy sectors (Paulo *et al.*, 2020). Additionally, the study adhered to PRISMA guidelines to maintain transparency and methodological rigor throughout the review process (Nwamekwe *et al.*, 2025e; Igbokwe *et al.*, 2025a; Onyeka *et al.*, 2024~~a~~).

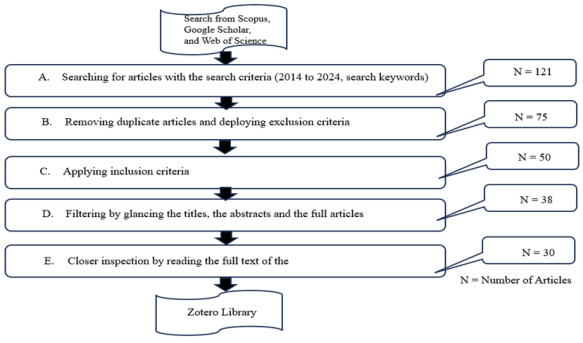

Fig. 3: Flow chart for the search of the articles used. (Source: Author's construct, 2026)

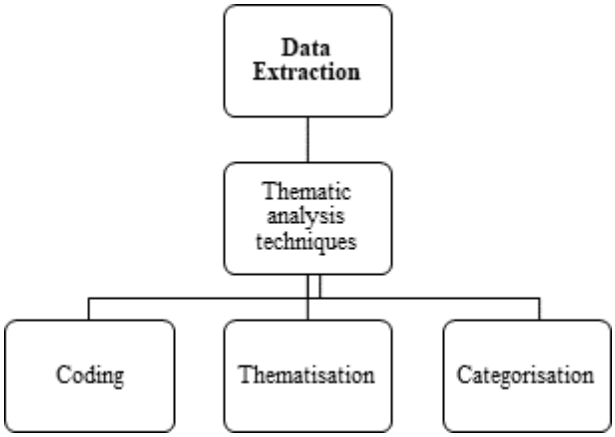

Fig. 4: Data extraction flowchart.
(Source: Author's construct, 2026)

Inclusion and Exclusion Criteria

A structured framework was applied to identify, screen, and select studies that closely aligned with the research objectives (Fig. 4). This approach ensured that the review maintained high analytical rigor and methodological quality.

Inclusion Criteria

The following criteria were used to determine the eligibility of studies:

Year range: Studies published between 2014 and 2024 were included to ensure coverage of recent advancements in emerging technologies and business process optimization in blue economy sectors.

Subject areas: The review focused on studies related to emerging technologies, business process optimization, and blue economy sectors, with emphasis on industrial applications.

Document type: Only peer-reviewed journal articles were considered to ensure the inclusion of high-quality primary research, empirical analyses, case studies, and theoretical papers.

Keywords: Articles that included specific keywords related to the research topic (as listed in Data Collection Method section) in their titles, abstracts, or main texts were included.

Language: Only studies published in English were considered to ensure accessibility, clarity, and ease of analysis.

Publication stage: Only final, fully published articles that had undergone rigorous peer review were included in the review.

Exclusion Criteria

The following exclusion criteria were applied:

Year range: Studies published before 2014 were excluded to maintain focus on contemporary research.

Subject areas: Articles unrelated to emerging technologies, business process optimization, or blue economy sectors were excluded.

Document type: Conference papers, book chapters, technical reports, and general literature reviews were excluded to focus on primary research.

Language: Studies published in languages other than English were excluded to ensure consistency in the interpretation and communication of findings.

Publication Stage: Articles labelled as "Articles in Press" were excluded to maintain methodological reliability by considering only fully published studies.

By employing these inclusion and exclusion criteria, this systematic review ensured a focused and high-quality selection of relevant studies from fields such as Industrial Engineering, Production Engineering, Economics, Computer Science, Data Science, and Operations Management. These criteria ensured that the review synthesized insights from rigorously vetted literature, focusing on the integration of Machine Learning, AI, IoT, Blockchain, and other emerging technologies in optimizing business processes within blue economy sectors.

Data Analysis Method

The collected data was analysed using thematic analysis to identify key themes and categorize them according to industry-relevant technological applications. Thematic analysis is a widely used qualitative method that enables researchers to detect patterns, interpret trends, and draw insights from qualitative datasets (Nwamekwe *et al.*, 2025j). The analysis followed a structured approach:

Familiarization with data: Initial review of included studies to gain an understanding of key concepts and findings.

Coding: Identification of recurring themes related to technology adoption, business process optimization, and blue economy development.

Categorization: Grouping themes under broader categories, such as policy implications, technological challenges, and sustainability impacts.

Interpretation: Synthesizing findings to highlight key insights, research gaps, and policy recommendations.

By utilizing thematic analysis, the study provides a structured and nuanced exploration of how emerging technologies enhance business processes in Anambra State's blue economy sectors. The results from this analysis contribute to policy formulation, industry innovation strategies, and future research directions.

Study Area: Anambra State's Industrial Landscape

Anambra State, located in southeastern Nigeria, has been experiencing a notable expansion in its industrial sector, particularly within blue economy-related industries (Nwamekwe and Igbokwe, 2024a). This study focuses on significant industrial clusters such as the Onitsha industrial hub, which serves as a critical nexus for various

manufacturing and processing activities linked to the blue economy. The region's strategic positioning along the Niger River presents unique opportunities for the development of maritime and aquaculture industries, potentially enhancing local economic growth and sustainability (Nwafor, 2024; Okpala *et al.*, 2024b; Nwamekwe *et al.*, 2025d).

The examination of businesses operating within these sectors is crucial for evaluating the adoption of emerging technologies, including automation, AI, blockchain, and the IoT. These technologies hold the potential to optimize business processes, thereby improving efficiency and productivity in Anambra State's industrial landscape (Udeogu *et al.*, 2024; Obianefo *et al.*, 2023; Igbokwe *et al.*, 2024b). A targeted assessment of the current technological integration practices among industries engaged in blue economy activities will provide vital insights into the effectiveness of technological adoption and the challenges that hinder progress. Such understanding can facilitate the development of strategic frameworks aimed at fostering technological innovations for economic sustainability in the region (Obianefo *et al.*, 2023; Nwamekwe *et al.*, 2025i).

Ethical Considerations

The ethical considerations of this study adhered to rigorous research guidelines essential for maintaining integrity and protecting participants' rights. Informed consent was obtained from all participants before their engagement in surveys or interviews, ensuring they were fully briefed on the study's purpose and implications, as detailed in prior research frameworks (Azzolini *et al.*, 2022; Igbokwe *et al.*, 2025b; Nwamekwe *et al.*, 2025f). This process is fundamental in upholding ethical standards that prevent coercive participation and safeguard participant autonomy (Benameur

Table 1: Key themes, sub-themes, and insights on emerging tech integration.

Theme	Sub-Themes	Insights
1. Infrastructure and Access	- Connectivity - Power Supply - Cost of Technology	Reliable infrastructure is a fundamental enabler for tech adoption. Many businesses face unreliable internet connectivity and electricity supply, which hampers the use of IoT devices and other digital tools. The high cost of acquiring and maintaining new technologies (hardware, software, and connectivity) also limits adoption, especially for smaller enterprises with budget constraints.
2. Skills and Knowledge	- Technical Skills Gap - Training and Capacity Building - Change Management	The human capital dimension is critical. There is a notable skills gap – many workers and managers lack the technical expertise to implement and manage emerging technologies effectively. The study found low awareness in some firms about how technologies like data analytics or automation could improve their operations. Continuous training and capacity-building programs are needed to upskill employees. Additionally, change management emerged as a sub-theme: resistance to new processes and fear of the unknown can impede technology integration, indicating the need to cultivate a culture open to innovation.
3. Operational Efficiency and Process Improvement	- Automation of Tasks - Data-Driven Decision Making - Quality and Speed Improvements	A positive theme is the clear efficiency gains achieved by those who have embraced technology. Participants noted that automating routine tasks (for example, using software or robotics for processing or inventory management) has reduced errors and freed up time for higher-value activities. Better data collection (through sensors or IT systems) enables data-driven decision making, improving planning and resource allocation. Overall, emerging tech integration is linked to faster operations, improved product/service quality, and enhanced ability to meet customer demand. Companies that adopted digital tools in logistics or production reported more streamlined workflows and cost savings in the long run.
4. Challenges and Barriers	- Financial Constraints - Regulatory and Policy Gaps - Maintenance and Security Concerns	Despite the benefits, significant barriers hinder widespread adoption of technology. Financial constraints are a common issue: beyond initial investment costs, businesses struggle with accessing capital or credit to fund technology projects. Regulatory uncertainty and the lack of clear policies for tech use in some blue economy activities (for instance, unclear guidelines on drone usage for marine surveillance or a lack of standards for digital transactions in fisheries) create hesitation. Participants also mentioned bureaucratic bottlenecks in obtaining approvals for new tech-driven initiatives. Furthermore, maintaining advanced equipment can be difficult – there are concerns about inadequate local technical support and the availability of spare parts for high-tech systems. Cybersecurity and data privacy emerged as related worries, as companies recognize the risks associated with digital operations but feel ill-prepared to manage them.
5. Enabling Environment and Sustainability	- Government Support and Policy Initiatives - Public-Private Partnerships - Environmental Sustainability Goals	This theme captures the external support system and the alignment with sustainability objectives. The research highlights that government involvement is pivotal: where there are supportive policies, incentives, or pilot programs from government agencies, businesses find it much easier to adopt new technologies. Public-private partnerships (e.g. collaborations between tech firms, universities, and local industry) were identified as a way to share knowledge and reduce costs – some stakeholders pointed to successful pilots in other regions as models. Importantly, the sustainability aspect of the blue economy is a driving consideration: companies are increasingly aware that technologies can help them comply with environmental regulations and adopt greener practices. For instance, using sensors to monitor water quality helps fish farms prevent pollution and adhere to environmental standards. This alignment of technology use with sustainability goals not only protects the ecosystem but also enhances corporate social responsibility profiles, creating an added incentive for tech integration.

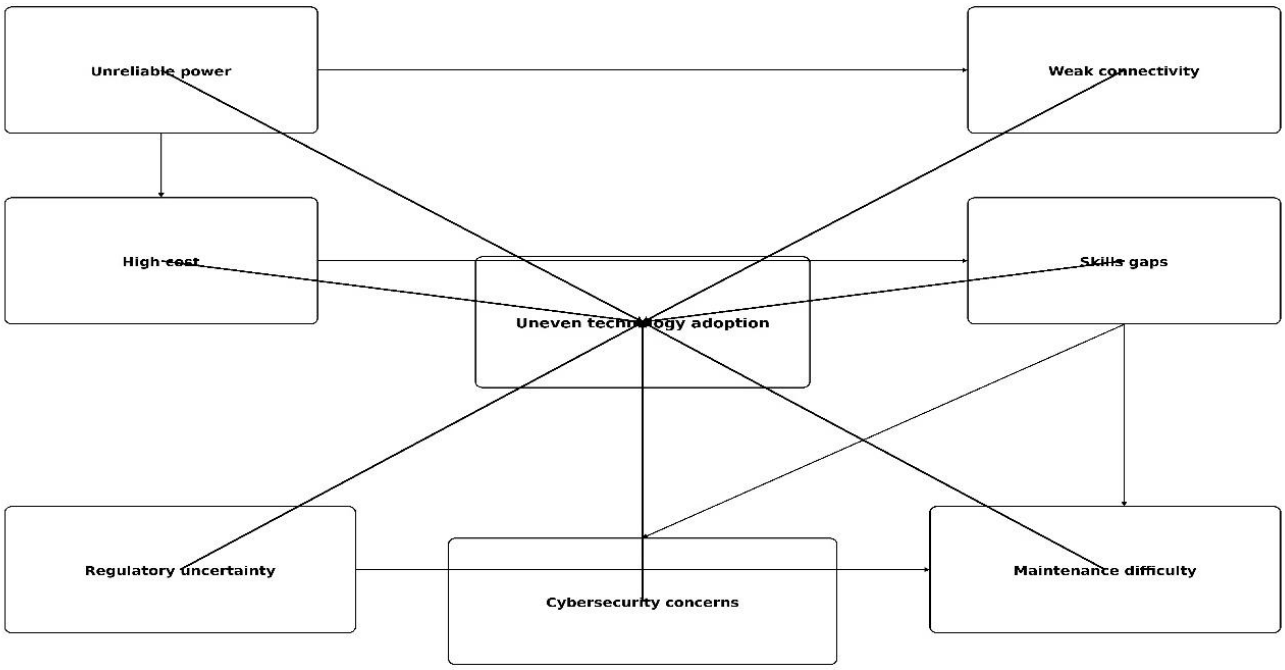

Fig. 5: Barrier interaction map or causal network of adoption constraints. (Source: Author's construct, 2026)

et al., 2020; Okpala *et al.*, 2025b). Furthermore, the study ensured confidentiality and anonymity for all respondents, thereby minimizing the risk of personal data exposure. Participants' information was stored securely, employing measures to prevent unauthorized access, consistent with best practices in ethical research conduct (Sullivan *et al.*, 2018; Nwamekwe *et al.*, 2025g). Before commencing data collection, ethical approval was procured from relevant institutional review boards, demonstrating compliance with established ethical protocols (Nwamekwe *et al.*, 2024c). Such adherence not only enhances the credibility of the research but also reinforces the commitment to ethical standards in conducting studies involving human subjects in the context of emerging technologies and business process optimization in Anambra's blue economy sectors.

By adopting this rigorous methodological framework, the study ensures the reliability and validity of findings, providing actionable insights for policymakers, industry stakeholders, and researchers interested in leveraging emerging technologies for business process optimization in blue economy sectors.

RESULTS AND DISCUSSION

Key Themes Identified in Technology Integration

The thematic analysis revealed several key themes regarding the integration of emerging technologies into business processes in Anambra State's blue economy sectors. These themes reflect both the drivers of technology adoption and the challenges faced by organizations. Table 1 below summarizes the main themes, associated sub-themes, and core insights from the study.

Fig. 5 presents the technology adoption barriers as an interacting constraint system rather than as independent lists. It uses the research-identified challenges, unreliable power, weak connectivity, high cost, skills gaps, regulatory uncertainty, maintenance difficulty, and cybersecurity concerns, and shows how they converge on uneven adoption while also reinforcing one another. This makes the manuscript's policy argument sharper and more structurally coherent.

These themes in Table 1 illustrate a balanced view of technology integration in Anambra's blue economy sectors. On one hand, there is enthusiasm about the efficiency and productivity improvements that digital tools and automation can bring. On the other hand, foundational issues like infrastructure and skill deficits, along with financial and regulatory hurdles, are significant impediments. The presence of an enabling environment – through supportive policy and partnerships – can tip the scales by addressing many of these barriers. In sum, the case study suggests that achieving the full benefits of emerging technologies in blue economy businesses requires not just the technologies themselves, but also investments in people, infrastructure, and collaborative frameworks.

SWOT Analysis of Tech Integration in Anambra's Blue Economy

To complement the thematic findings, a SWOT analysis was conducted to evaluate the Strengths, Weaknesses, Opportunities, and Threats associated with integrating emerging technologies into Anambra State's blue economy sectors. This analytical model provides a concise overview of internal factors (strengths and weaknesses inherent in the current context) and external factors (opportunities and threats in the broader environment) that affect technology-driven business process enhancement.

In Table 2, the SWOT analysis underscores that Anambra State has notable strengths to build upon, such as an entrepreneurial workforce and some government-led

Table 2: SWOT analysis – emerging technology integration in Anambra's blue economy.

Strengths (internal positives)	Weaknesses (internal negatives)
- Growing awareness of digital transformation benefits among forward-looking businesses. - Presence of a young, tech-savvy workforce eager to learn and innovate. - Some ongoing modernization projects (e.g. state initiatives to upgrade infrastructure) providing a foundation for tech adoption.	- Inadequate infrastructure in many areas (unstable power supply, limited broadband coverage) hampering continuous tech usage. - Limited access to finance for tech investments, especially among small enterprises. - Gaps in technical expertise and digital literacy within the existing workforce, leading to reliance on external support.
Opportunities (external positives)	**Threats (external negatives)**
- Supportive policy climate: government recognition of the blue economy (e.g. Nigeria's new Marine and Blue Economy ministry) creates avenues for funding and reforms. - Rapid advancement and falling costs of technologies globally, making solutions more affordable over time. - Potential partnerships with international development agencies and tech companies focusing on sustainable blue economy solutions.	- Economic volatility and inflation can reduce the ability of businesses to invest in new technologies, stalling adoption plans. - Fast-changing technology landscape – risk that systems adopted today could become obsolete if not upgraded, creating a continuous cost burden. - Cybersecurity threats: greater connectivity exposes businesses to data breaches or cyber-attacks, and many may not have protections in place.

improvements, but also faces internal weaknesses like infrastructural gaps and funding difficulties. Externally, the environment offers promising opportunities – from favourable policy attention to technological advancements – yet also presents threats such as economic challenges and security risks. Stakeholders should leverage strengths and opportunities (e.g. capitalize on policy support and youth skills) while mitigating weaknesses and threats (e.g. improving infrastructure and instituting cybersecurity measures).

Fig. 6 organizes the study's technology claims by sector and direct business value. It maps specific technologies to their most relevant operational uses in aquaculture, fisheries, and inland transport or logistics, then connects those uses to improvements such as stronger monitoring, better planning, traceability, reduced duplication, and clearer operational control. It improves clarity by converting dispersed narrative examples into a single applied cross-sector visual.

Comparative Analysis Across Blue Economy Sectors

Another layer of analysis was performed to compare how emerging technology integration differs across key blue economy sectors in Anambra State. Two representative sectors were examined: fisheries/aquaculture and inland water transportation (port and logistics). This comparative view highlights sector-specific contexts, which can inform

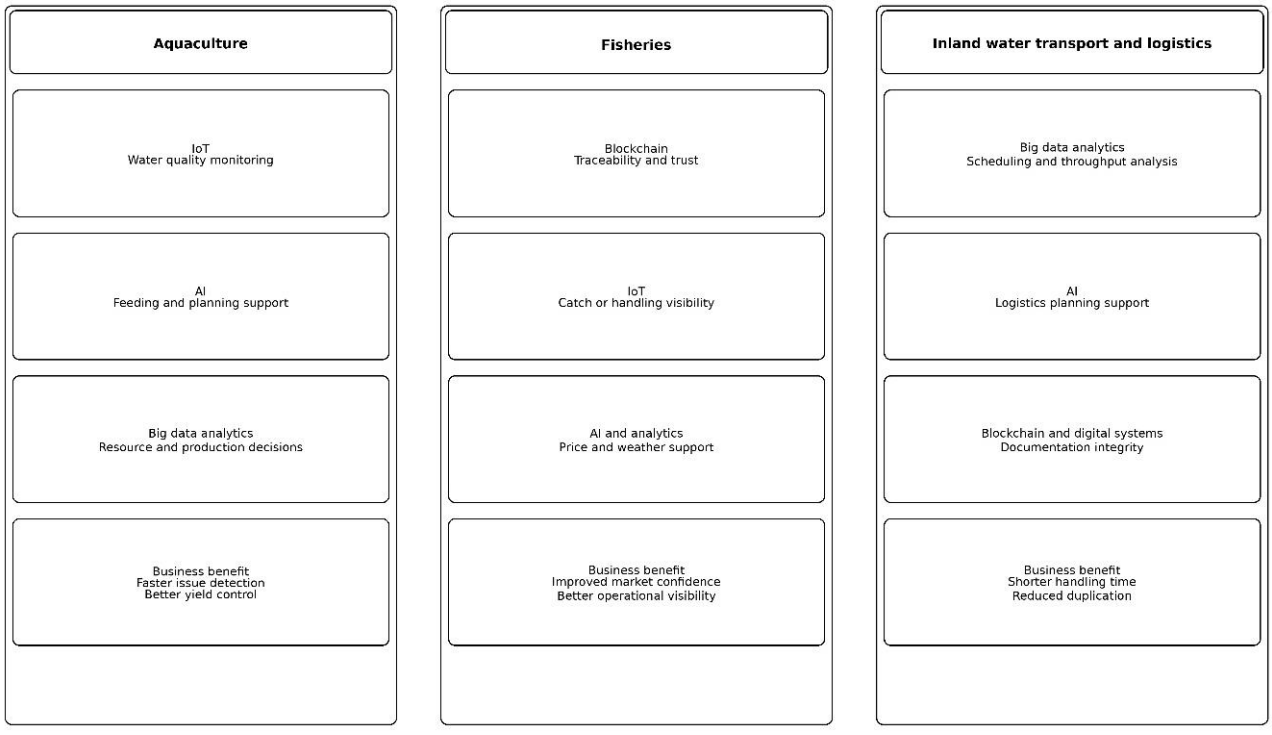

Fig. 6: Sector-specific technology to benefit mapping diagram.

Table 3: Comparison of tech integration in fisheries vs. inland water transport.

Aspect	Fisheries/Aquaculture	Inland Water Transport (River Port and Logistics)
Current Tech Adoption	Generally low-tech, though a few forward-thinking fisheries have started using sensors and IoT-based monitoring for water quality and pond conditions. For example, pilot projects have introduced IoT sensor systems to track parameters like temperature, pH, and oxygen in fish ponds in real-time. However, most small-scale fish farmers still rely on traditional methods with minimal automation.	A gradual shift toward digital systems is underway in port operations. Some processes, such as cargo tracking and communications, are being computerized, and there are plans to implement more advanced tools (e.g. an electronic single-window system for documentation). Still, many operations remain partially manual or paper-based, especially in administrative tasks. The adoption of cutting-edge technologies like AI for logistics optimization is in very early stages.
Key Benefits Observed	Farms that leverage emerging tech have reported better oversight of production and resource use. Automated monitoring leads to quicker detection of issues (e.g. poor water quality), reducing fish mortality and improving yields. Mobile applications are also helping connect fishermen and farmers to markets and information (weather, prices) more efficiently. Overall, even modest tech interventions have enhanced productivity and profitability for early adopters.	Digitalization in the transport sector is improving efficiency and throughput. For instance, using software to schedule and track shipments has started to shorten cargo handling times and reduce errors in documentation. Replacing paper-based processes with electronic systems minimizes duplication of efforts and port bottlenecks. In the long run, these improvements can increase the port's capacity and reliability, attracting more business to the region. Additionally, technology aids safety (e.g. better communication systems for river navigation improve accident response).
Main Challenges	A major challenge is the limited financial and technical capacity of local fishery operators. Many cannot afford modern equipment or lack knowledge on how to maintain sensor systems and machines. Training is a hurdle – it takes time and resources to teach farmers to use smartphone apps or automated feeders. There are also practical issues like devices getting damaged in harsh, wet farm environments and difficulties in servicing equipment in remote rural areas.	The transport sector faces infrastructural and institutional challenges. Inconsistent power supply and network connectivity at the port cause downtime for digital systems. There may be resistance from some staff accustomed to the old ways of doing things, slowing down the implementation of new software or procedures. Moreover, clear policies or standards are needed to integrate systems across agencies (customs, port authority, shippers); without coordination, tech adoption can hit bureaucratic snags. Funding for large-scale upgrades (such as smart port infrastructure) is also an obstacle, often requiring government or private investment that can be slow to materialize.
Overall Adoption Level	Early-stage (nascent). Outside of a few innovative enterprises, the sector is largely in the infancy of tech integration. The typical fish farm or fishery cooperative in Anambra is only beginning to explore what digital tools can do, so adoption is patchy and pilot-based. There is significant room for scaling up successful tech-driven models across the broader community of fish farmers.	Transitional. The inland water transport sector is in a transitional phase – neither fully traditional nor fully modernized. Key stakeholders (including the state government) have signalled intentions to modernize port operations and some initial steps have been taken. However, a fully "smart" port or integrated digital logistics system is still a work in progress. In summary, adoption is moderate and picking up pace, but comprehensive technology integration has yet to be achieved.

more tailored strategies. Table 3 provides a side-by-side comparison of these sectors on several aspects of technology adoption.

From this comparative analysis in Table 3, it is evident that both sectors recognize the value of emerging technologies but are at different points on the adoption curve. The aquaculture/fisheries sector, dominated by many small players, shows pockets of innovation amid generally low adoption; its needs centre around affordable, easy-to-use technologies and training for rural users. The inland waterways transport sector, being more centralized (around port facilities and trading companies), has seen more top-down modernization efforts, yet it grapples with infrastructure and coordination issues. Strategies to enhance tech integration must therefore be nuanced: one size will not fit all, and sector-specific plans are essential.

Fig. 7 converts the comparative discussion into a structured maturity matrix. It places fisheries, aquaculture, inland water transport, and related activities along a progression from nascent to more integrated adoption stages, using the manuscript's own distinctions between traditional practice, pilot activity, partial digital reform, and uneven modernization. It strengthens the sectoral argument by making differences in the adoption stage immediately visible.

Recommendations for Industry Stakeholders and Policymakers

The findings show a clear pattern. Technology adoption in Anambra State's blue economy sectors is shaped by five linked conditions: infrastructure quality, access to finance, workforce capability, regulatory clarity, and the practical value firms derive from digital tools in daily operations. The recommendations in this section respond directly to those conditions and remain consistent with the thematic results, SWOT analysis, and sector comparison presented in the manuscript. The analysis shows that the main issue is not a lack of relevance of emerging technologies. The main issue is the weakness of the conditions required for sustained use. Businesses in fisheries and aquaculture face low digital readiness, limited capital, and limited technical support. Inland transport and logistics show stronger movement toward digital systems, yet progress remains uneven because infrastructure, institutional coordination, and implementation

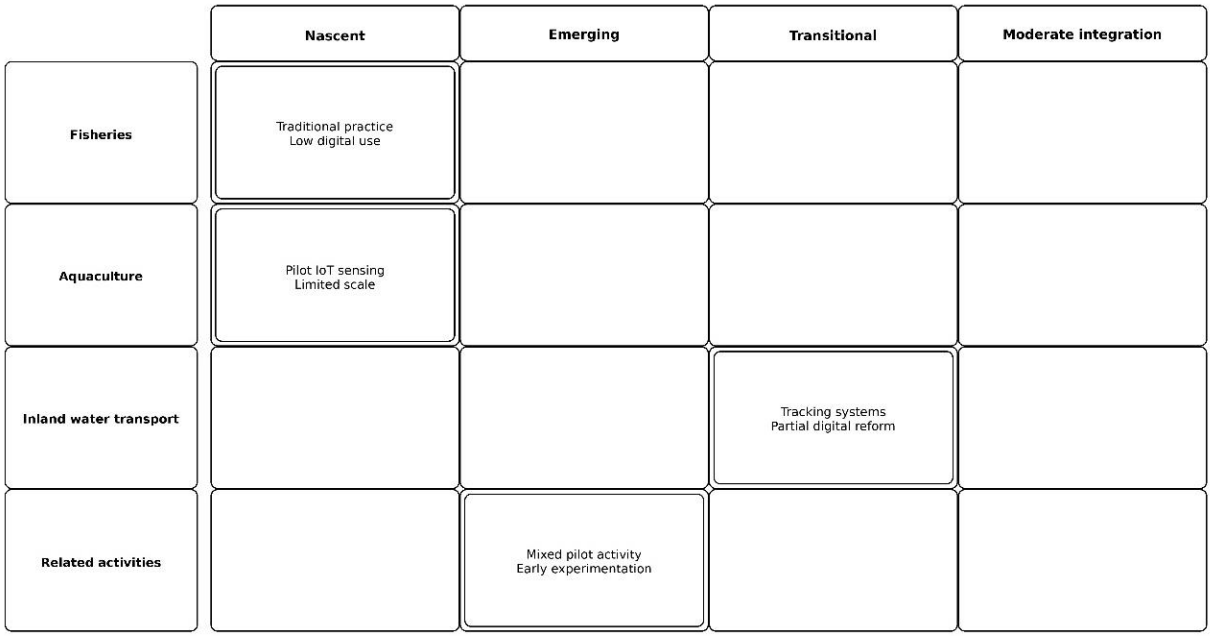

Fig. 7: Technology adoption maturity matrix across blue economy sectors in Anambra state.

standards remain weak. These differences matter. They show why recommendations must be practical, staged, and sensitive to sector conditions. The policy direction emerging from this study is straightforward. Technology integration should be treated as an operational reform agenda, not as a symbolic modernization agenda. For industry actors, this means selecting technologies that solve concrete process problems such as poor monitoring, weak traceability, slow documentation, delayed communication, and avoidable waste. For policymakers, this means building the enabling structure required for firms to adopt, maintain, and scale such systems over time. The recommendations below are therefore framed as implementation actions linked to the barriers and opportunities identified across the study.

For Industry Stakeholders (Businesses and Sector Participants)

Industry stakeholders should approach digital integration as a disciplined business improvement process. The study shows that firms obtain stronger value from technology when adoption is tied to a specific operational need. This includes monitoring water quality in fish production, reducing record errors in logistics, improving scheduling, strengthening traceability, and shortening decision cycles. Firms should therefore begin with process diagnosis. Management should identify where delays, losses, duplication, low visibility, or weak coordination occur, then match a digital solution to that specific pain point. This approach reduces wasteful investment and improves the likelihood of measurable returns. Investment in basic enabling infrastructure should be treated as a first operational requirement. For many businesses, the usefulness of digital tools is constrained by irregular power supply and weak connectivity. Firms that intend to adopt sensors, cloud-based records, digital payment systems, automated communication tools, or monitoring dashboards should first secure minimum functional conditions for continuity. This includes backup power for critical equipment, protected device storage, stable internet access at operational sites, and simple data storage routines. Without these foundational conditions, even low-cost digital tools become unreliable. Human capital development should move from an optional activity to a core business function. The findings show that technical skill gaps remain one of the strongest barriers to effective adoption. Many firms still operate with limited digital confidence among supervisors, operators, and administrative staff. Businesses should respond with structured training tied to job tasks. Staff in aquaculture should be trained in sensor reading, data logging, app-based monitoring, and basic maintenance. Staff in logistics should be trained in digital documentation, shipment tracking interfaces, electronic communication systems, and data interpretation for routine planning. Training should not end at initial deployment. Refresher sessions, peer support arrangements, and task-based learning should be built into normal operations so that knowledge does not remain concentrated in one individual.

Small-scale pilot implementation is the most suitable adoption route for many firms in the study area. The sector evidence shows that businesses face cost pressures and operational uncertainty. Pilot projects reduce exposure while generating practical learning. A fish farm, for example, should begin with one pond-based sensor unit to test reliability, monitoring discipline, and response value before extending deployment across all ponds. A logistics operator should start with one digitized documentation stream or one route-tracking module before committing to full process digitization. This staged approach produces operational evidence, reveals maintenance demands, and allows firms to correct design errors early. Industry associations, cooperatives, and cluster arrangements should take a stronger role in reducing the cost of adoption. The study identifies fragmented effort as a constraint, especially among smaller enterprises. Individual firms often lack the purchasing power,

technical reach, and knowledge base needed for sustained technology use. Collective action offers a better path. Fishery cooperatives should pool demand for advisory support, device procurement, and maintenance services. Logistics clusters should share training resources, software support arrangements, and implementation lessons. Local partnerships with universities, technical institutes, and start-up providers are also important because they improve adaptation of digital tools to local operating conditions rather than imported assumptions. Data use should become a routine management practice. Many firms already generate useful information through production records, sales logs, transport schedules, fuel use, input costs, and customer response patterns. Yet much of this information remains underused. Businesses should establish simple internal analytics routines based on weekly and monthly reviews of key operational indicators. In fisheries, this includes growth rates, feeding cycles, mortality events, pond conditions, and market timing. In logistics, this includes transit time, document processing time, idle time, route delay, cargo handling duration, and service error frequency. Even basic spreadsheet-based analysis improves visibility and supports better decisions on scheduling, input use, staffing, and service quality.

Maintenance planning should be built into every technology decision from the start. The findings show that adoption failures often emerge after installation, when equipment faults, spare parts shortages, or technical support delays disrupt operations. Firms should avoid treating maintenance as an afterthought. Every digital investment should include a service plan, responsibility structure, replacement schedule, and budget line for upkeep. Equipment exposed to wet environments, dust, heat, vibration, or unstable electricity should receive special protection. Local support availability should be considered before procurement decisions are made. Cybersecurity and data protection also require direct attention. As more firms shift from paper-based operations to connected systems, exposure to data loss, unauthorized access, and operational disruption increases. Many smaller firms underestimate this risk. Businesses should adopt simple but disciplined safeguards. These include password control, user access restriction, periodic data backup, antivirus protection, and basic staff awareness on phishing and unsafe device use. This is especially important in sectors handling transaction records, customer information, inventory logs, and operational monitoring data. Change management should be handled deliberately. Resistance to new systems often reflects uncertainty, fear of failure, and weak communication rather than outright rejection of innovation. Managers should explain why a digital system is being introduced, what problem it is expected to solve, what support staff will receive, and how performance will be assessed. Involving staff in pilot design and workflow adaptation improves acceptance and strengthens implementation quality. The study shows that firms progress faster when technology is presented as a tool for easing work, reducing errors, and improving control, rather than as a top-down disruption.

For Policymakers (Government and Regulators)

Policymakers should treat digital integration in the blue economy as an economic development priority linked to productivity, sustainability, and regional competitiveness. The findings show that private effort alone will not resolve the structural barriers slowing adoption. Public action is needed in infrastructure, finance, standards, training, and institutional coordination. Without these enabling conditions, technology adoption will remain uneven, fragmented, and concentrated among a small number of better-positioned firms. Infrastructure improvement should be the first policy priority. The manuscript consistently identifies unstable electricity and weak internet connectivity as major constraints across sectors. Government action should focus on industrial clusters, river-linked commercial zones, port facilities, fish production areas, and rural operation points that support blue economy activity. Reliable electricity is essential for sensors, communication systems, cold storage, digital records, and monitoring equipment. Broadband expansion is equally important for cloud access, mobile platforms, digital transactions, and remote support. Public investment, targeted concession arrangements, and structured public-private infrastructure partnerships should be directed toward these high-impact zones. Financial support mechanisms should be designed around the realities of small and medium enterprises. Many firms in fisheries, aquaculture, and related processing activities lack the capital required for technology acquisition and integration. Policymakers should introduce targeted support schemes tied to approved business improvement technologies. These include tax relief on eligible equipment, import duty reduction for sector-relevant digital tools, matching grants for pilot deployments, and low-interest financing for SMEs implementing monitored technology projects. Such schemes should include accountability conditions so that funding supports real operational use rather than one-time procurement.

Capacity building should be organized as a state-supported skills program rather than a scattered set of isolated workshops. The study shows that workforce capability remains a major adoption gap. Government ministries, technical institutions, universities, and industry bodies should jointly develop sector-specific training modules. Aquaculture training should address digital pond monitoring, sensor interpretation, feed optimization, water quality management, and digital market linkage. Inland transport training should address electronic documentation, cargo tracking, route coordination, data handling, and digital communication systems. Certification pathways should be practical and job-oriented, with direct relevance to operating firms. A coherent regulatory framework is also required. Many businesses hesitate when rules are unclear or fragmented. The study identifies policy uncertainty as a real barrier, especially in relation to digital transactions, environmental monitoring tools, and inter-agency coordination in transport operations. The government should produce a state-level digital strategy for blue economy sectors with clearly defined implementation priorities, operating standards, data expectations, and compliance procedures. This framework should align with national policy directions related to marine and blue economy development while addressing the specific institutional realities of Anambra State. Clear rules reduce hesitation, improve investment confidence, and support

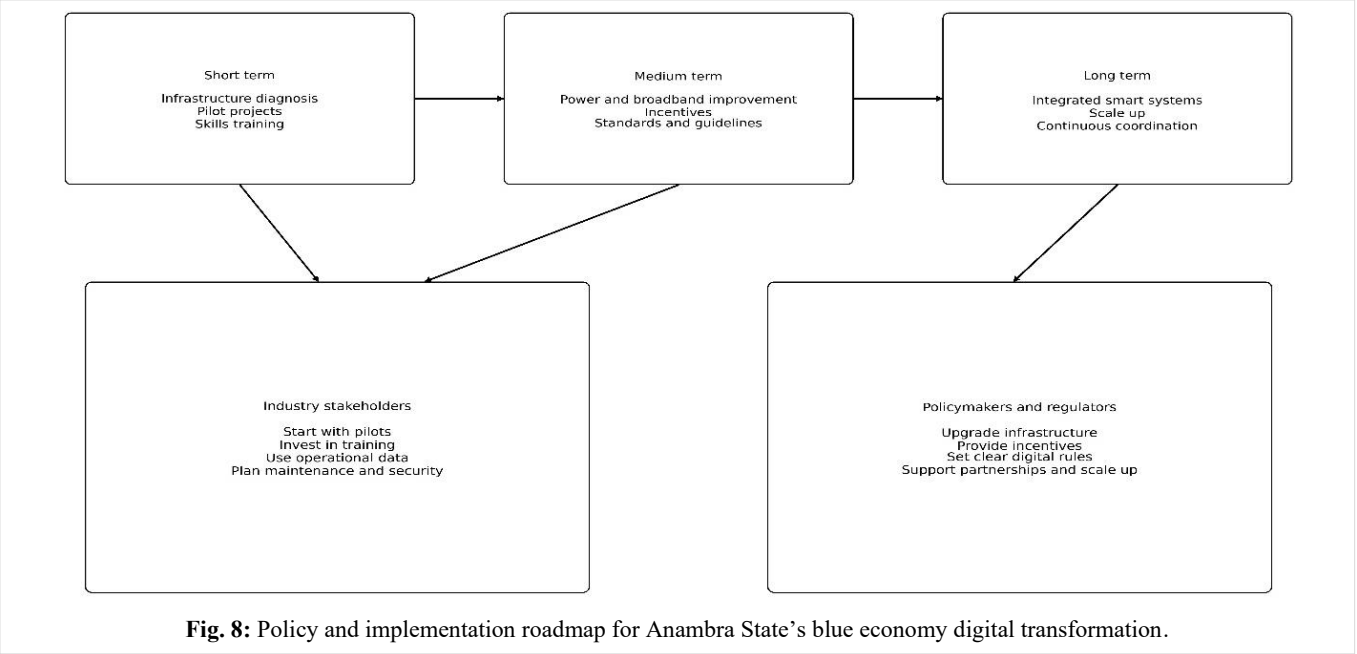

Fig. 8: Policy and implementation roadmap for Anambra State's blue economy digital transformation.

interoperability across firms and agencies. Policy support should also encourage environmental compliance through technology-enabled monitoring. The manuscript shows that sustainability is not a separate concern from business performance. In fish production, sensor-based water monitoring strengthens environmental control while reducing stock loss. In logistics, digital coordination reduces waste, duplication, and avoidable delay. Policymakers should therefore design environmental and operational standards that encourage monitored compliance rather than paper-based reporting alone. This approach improves accountability and creates demand for useful digital tools.

Pilot projects should be used as public demonstration platforms. The study points to the value of visible examples in stimulating confidence and adoption. The government should support demonstrator projects with clear sector relevance. A smart fish farm pilot with sensor-based monitoring, solar-supported cold storage, digital feed records, and mobile market linkage would provide a tangible model for local operators. A smart river-port pilot with electronic documentation, cargo tracking, entry management, and coordinated agency data flows would serve the same function for inland transport and logistics. These pilots should be documented, evaluated, and used as learning platforms for wider sector replication. Public-private partnerships should move beyond general advocacy into structured implementation arrangements. Technology providers, university researchers, sector associations, financiers, and government agencies each hold part of the capacity needed for successful reform. The state should establish a recurring coordination mechanism where these actors review progress, share barriers, align interventions, and identify opportunities for scaling successful models. This will reduce duplication, improve institutional learning, and create a more coherent reform path across sectors. Policymakers should also give attention to maintenance ecosystems. Technology adoption weakens when equipment fails, and no local support structure exists. Public support for technician development, spare-parts channels, device servicing networks, and local integration expertise would address a major source of post-adoption failure. This is especially important in wet, remote, or infrastructure-poor operating conditions where routine servicing is more difficult.

Finally, implementation should follow a phased logic. Short-term actions should focus on infrastructure hotspots, training pilots, and demonstration projects. Medium-term actions should focus on financing schemes, regulatory consolidation, and sector-wide standards. Long-term actions should focus on scaling, institutional integration, advanced analytics, and stronger cross-sector digital linkages. This phased structure aligns with the policy roadmap implied in Fig. 8 and fits the maturity differences observed across the sectors.

CONCLUSION AND RECOMMENDATIONS

The study set out to examine how emerging technologies improve business processes in Anambra State's blue economy sectors and what factors shape their adoption. The evidence reviewed across the manuscript leads to a consistent result. Emerging technologies improve operational performance where firms have the infrastructure, skills, financing, and institutional support needed for sustained deployment. Where these conditions are weak, adoption remains partial and unstable. The issue, therefore, is not whether the technologies are relevant. The issue is whether the business and policy environment supports effective use. Across the sectors examined, digital tools show direct process value. They improve monitoring, speed up communication, reduce documentation errors, support better planning, and strengthen operational visibility. In aquaculture and fisheries, technologies such as sensors, digital communication tools, and basic analytics improve production oversight and response to changing conditions. In inland transport and logistics, digital systems improve tracking, coordination, documentation flow, and service reliability. These benefits confirm the core proposition of the study, which is that

emerging technologies are practical instruments for business process optimization in blue economy sectors.

At the same time, the study shows that benefits are not automatically realized. Infrastructure weakness remains one of the strongest constraints. Unstable power supply and weak connectivity undermine the continuity of digital operations. Financial pressure limits procurement and scaling, especially among small operators. Skills gaps weaken implementation and reduce the value firms derive from installed systems. Regulatory uncertainty creates hesitation. Maintenance and cybersecurity concerns further slow adoption. These barriers interact with one another, which means isolated interventions will produce limited results. The broader implication is clear. Technology integration in Anambra State's blue economy should be pursued as a coordinated development effort involving firms, regulators, educators, financiers, and technology partners. Sustainable progress depends on joint action. Where firms invest in useful systems, but public infrastructure remains weak, adoption will stall. Where government promotes digital reform but firms lack the skill or incentive to act, uptake will remain shallow. Progress requires alignment between operational need, technical capacity, and public support.

Summary of Findings

The findings of the study point to five major conclusions.

First, emerging technologies have a clear role in improving business processes across blue economy sectors in Anambra State. The strongest gains relate to operational efficiency, process control, traceability, real-time visibility, and improved quality of decisions. Businesses that adopt digital tools report smoother workflows, reduced duplication, quicker response to operational issues, and stronger service coordination.

Second, technology adoption remains uneven across sectors. Fisheries and aquaculture are still at an early stage, with isolated examples of digital monitoring and mobile-enabled coordination. Inland water transport and logistics show a more advanced but incomplete pattern, with partial digitalization in documentation, communication, and cargo-related processes. This confirms that sector context strongly shapes adoption pace and form.

Third, infrastructure deficits remain a major structural barrier. The review repeatedly identifies electricity instability and limited internet access as obstacles to continuous digital operation. These deficits weaken the reliability of sensors, communication tools, cloud platforms, and electronic record systems.

Fourth, human capital and organizational readiness strongly influence outcomes. Many businesses lack the technical expertise needed to adopt, manage, and maintain digital systems. Resistance to new work methods also slows implementation. Training, process adaptation, and change management; therefore, emerge as essential conditions for successful integration.

Fifth, policy and institutional support are decisive. Where supportive frameworks, incentives, partnerships, and pilot programs exist, firms are more likely to experiment with and sustain digital innovations. Where policy is vague or fragmented, adoption remains cautious and uneven. The enabling environment is therefore central to the digital transition of the blue economy sectors examined in this study.

Policy and Practical Recommendations

The practical response to these findings should follow two parallel tracks, one for policymakers and one for industry stakeholders.

For policymakers, the most urgent priority is to improve the enabling conditions for digital operations. This includes power reliability, broadband access, financing support, regulatory clarity, and sector-specific capacity development. Policy should move from broad endorsement of innovation to targeted support for technologies with direct process value in aquaculture, fisheries, and inland logistics. Demonstration pilots, structured incentives, and coordinated stakeholder platforms are especially important because they reduce uncertainty and create visible examples of workable reform.

For industry stakeholders, the priority is disciplined and problem-oriented adoption. Firms should begin with technologies linked to a clear operational need, then expand gradually based on performance evidence. Investment in staff capability, routine data use, maintenance planning, and cybersecurity should form part of every digital transition plan. Cooperative action through associations and clusters should also be strengthened so that smaller firms do not bear the full cost of experimentation and technical support alone.

Taken together, the policy and practical recommendations of this study support a phased digital transition model. In the short term, focus should be placed on foundational conditions such as infrastructure, pilot deployment, and workforce training. In the medium term, effort should shift toward scaling useful systems, standardizing processes, and strengthening data-driven decision routines. In the longer term, the sectors should move toward deeper integration of analytics, traceability systems, coordinated platforms, and environmentally responsive monitoring structures. This phased path reflects the maturity differences observed across the sectors and provides a more realistic route to sustained adoption.

Fig. 8 translates the recommendation section into a phased implementation roadmap for Anambra State's blue economy digital transformation. It separates short-term, medium-term, and long-term actions and aligns them with the responsibilities of industry stakeholders and policymakers. In that form, the manuscript's recommendations become an ordered implementation sequence built around infrastructure, incentives, skills, standards, partnerships, and scale-up.

Future Research Directions

The study also points to important directions for future research. One area requiring further work is longitudinal assessment. Most available evidence captures technology adoption at a particular point in time. There is a need for studies that track implementation over several years to determine whether early efficiency gains are sustained,

whether maintenance burdens increase, and whether firms deepen or abandon digital use after initial deployment. Another important direction is a deeper evaluation of next-generation technologies in blue economy settings. The current study focuses on AI, blockchain, big data analytics, and IoT as the main technology categories. Future work should examine the relevance of digital twins, predictive analytics for resource management, advanced traceability platforms, and integrated decision-support systems tailored to fish production, river transport, and related value chains. Comparative studies across regions are also needed. Anambra State offers a useful case, but broader comparison across other Nigerian states and similar developing contexts would improve understanding of which barriers are location-specific and which are systemic across blue economy sectors in low-resource settings. Such a comparison would also help identify transferable models of policy support and industry adaptation. Future research should also examine the social and labour dimensions of digital transition. Technology adoption affects work routines, skill requirements, supervision patterns, and access to opportunity. More evidence is needed on how digital integration influences employment quality, workforce inclusion, youth participation, and the position of smaller operators within changing sector structures. A final research priority is the measurement of business impact with stronger operational indicators. Future studies should move beyond general claims of improvement and assess concrete outcomes such as reduction in process time, documentation error rates, response time to production issues, waste reduction, stock loss, service reliability, and transaction transparency. This would strengthen the evidence base and support more precise investment and policy decisions.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

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