



ARTIFICIAL INTELLIGENCE ADOPTION AND OPERATIONAL EFFICIENCY IN THE NIGERIA CUSTOMS SERVICE: ASSESSING DIGITAL READINESS, EFFICIENCY GAINS, AND DATA INFRASTRUCTURE

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Abstract

This study examined the adoption of artificial intelligence (AI)-driven technologies and their implications for operational efficiency, transparency, and data-management systems within the Nigeria Customs Service (NCS). Specifically, it assessed the level of AI adoption, determined the extent to which AI influences customs efficiency and cargo clearance processes, and evaluated the adequacy of existing data-management infrastructure supporting AI deployment. The study adopted a descriptive quantitative research design, drawing data from a structured questionnaire administered to 500–600 customs officers selected through stratified random sampling across major customs formations in Nigeria. Data were analysed using descriptive statistics and inferential techniques, including regression analysis and chi-square tests. Findings revealed that AI adoption within the NCS is at a moderate but developing stage, characterised by partial integration of digital systems and uneven deployment across operational units. Results further showed that AI-driven technologies moderately enhance operational efficiency, improve cargo clearance speed, and strengthen transparency, although these gains remain constrained by institutional and infrastructural limitations. The study also found that existing data-management systems are only moderately adequate, with significant weaknesses in data integration, staff capacity, and system interoperability, despite relatively stronger performance in data security. The study concludes that while AI adoption is yielding measurable improvements in customs operations, its full potential remains limited by weak data infrastructure and incomplete institutional readiness. Strengthening data governance, enhancing digital capacity, and expanding AI integration are therefore critical for achieving full customs modernisation in Nigeria.

Keywords:

Artificial Intelligence, Customs Modernisation, Operational Efficiency, Data Management Systems, Nigeria Customs Service.

1.0 Introduction

The accelerating deployment of artificial intelligence (AI) across global public administration has reconfigured customs governance from labour-intensive bureaucratic structures into algorithmically enhanced systems designed to optimise trade facilitation, improve compliance, and suppress systemic inefficiencies. Across advanced and emerging economies alike, customs administrations are increasingly weaponising AI-driven instruments such as predictive analytics, machine learning, automated risk profiling, intelligent cargo inspection, and big data architectures to dismantle archaic operational bottlenecks and reduce the human vulnerabilities that historically enabled corruption, delay, and revenue leakage (World Customs Organization [WCO], 2022; Besson & Rowe, 2023). This technological recalibration has become particularly critical as international trade complexity intensifies and customs agencies are compelled to evolve from sluggish administrative apparatuses into digitally responsive gatekeeping mechanisms capable of facilitating seamless commerce while preserving national security interests (Akinola & Adeyemo, 2024).

Within Africa, the imperative for AI-enabled customs modernisation has gained increasing scholarly and policy traction, particularly as border institutions across the continent continue to grapple with infrastructural deficits, fragmented data ecosystems, and administrative inefficiency. Scholars such as Mutambara and Moeti (2022) argue that customs agencies in developing economies remain disproportionately trapped in obsolete manual systems that breed procedural opacity, weaken trade competitiveness, and sustain predatory bureaucratic cultures. Consequently, digital transformation through AI adoption is increasingly perceived not merely as an administrative luxury but as an existential requirement for institutional survival and economic relevance. In this regard, countries such as Rwanda, Kenya, and South Africa have demonstrated measurable progress in integrating digital customs frameworks, yielding improvements in cargo processing speed, revenue assurance, and anti-smuggling enforcement (Nabukenya, 2023; Wanjiku & Moyi, 2021).

Nigeria Customs Service (NCS), as one of the nation's foremost trade regulatory institutions, occupies a pivotal role in revenue generation, border security, and international trade governance. However, despite decades of reform rhetoric, the institution has often been criticised for operational inefficiencies, procedural opacity, weak technological sophistication, and endemic administrative inertia (Etienam & Ekpootu, 2023). Although initiatives such as the Nigeria Integrated Customs Information System (NICIS II), the Trade Modernisation Project (TMP), and the more recent B'Odogwu Unified Customs Management System signify strategic efforts towards digitalization, empirical evidence suggests that AI adoption within NCS remains uneven, infrastructurally constrained, and heavily dependent on broader data-management capabilities (Mohammed & Adamu, 2023; Obadiah et al., 2025). This suggests that while NCS is transitioning towards technological modernity, substantial questions persist regarding the true extent of AI integration and its practical consequences for customs efficiency and trade facilitation.

The effectiveness of AI systems within customs operations is fundamentally contingent upon robust data-management infrastructure, as algorithmic precision is directly shaped by data quality, interoperability, accessibility, and governance standards. Poorly structured databases, fragmented digital records, and weak institutional data cultures can transform AI systems into dysfunctional administrative ornaments rather than productive governance tools (Hassan, 2024). In Nigeria's context, longstanding concerns over poor digital infrastructure, weak cybersecurity preparedness, and inconsistent inter-platform compatibility threaten the transformative potential of AI within customs administration (Oseni, 2024). Thus, assessing NCS's AI readiness cannot be divorced from evaluating the institutional quality of its data ecosystems.

Furthermore, AI adoption in customs is not solely a technological phenomenon but a governance issue deeply linked to transparency, anti-corruption capacity, and national competitiveness. Effective AI deployment can potentially neutralize many discretionary loopholes traditionally exploited by bureaucratic predators through automated decision-making, electronic clearance systems, and real-time compliance monitoring (Björklund, 2022). For Nigeria, where customs inefficiency has historically imposed severe costs on trade competitiveness and private sector productivity, successful AI integration could significantly improve cargo-clearance timelines, enhance investor confidence, and strengthen fiscal sovereignty.

Despite growing policy enthusiasm, scholarly interrogation of AI-driven customs transformation within Nigeria remains relatively underdeveloped. Existing studies have predominantly focused on general automation, e-governance, or customs modernization, while insufficient attention has been paid to the empirical nexus between AI adoption, operational efficiency, and institutional data quality (Adewale & Hassan, 2024). This lacuna creates an urgent need for systematic inquiry capable of dissecting whether AI integration within NCS represents substantive transformation or merely superficial technological rebranding. Against this backdrop, this study investigates the current level of AI adoption within the Nigeria Customs Service, evaluates the extent to which AI-driven technologies influence customs efficiency, transparency, and cargo-clearance processes, and examines the adequacy of NCS data-management systems as foundational enablers of AI effectiveness.

2.0 Statement of the Problem

Despite the global shift towards intelligent customs systems powered by artificial intelligence (AI), Nigeria's customs administration continues to operate within a paradox of digital ambition and operational fragility. Across advanced customs regimes, AI has become a central instrument for dismantling bureaucratic sluggishness, eliminating discretionary bottlenecks, and optimizing cargo clearance through predictive analytics, automated risk profiling, and data-driven decision-making. However, in the Nigeria Customs Service (NCS), operational realities still reflect persistent inefficiencies characterized by procedural delays, inconsistent transparency, fragmented information systems, and uneven technological integration. These conditions suggest that while digital reforms have been introduced, the institutional machinery remains only partially transformed, thereby raising concerns about the actual depth of AI adoption and its functional relevance to customs efficiency.

A further critical problem lies in the uncertain extent to which AI-driven technologies have genuinely enhanced customs performance outcomes in Nigeria. Although systems such as

NICIS II and other automation platforms have been deployed, there remains insufficient empirical clarity on whether these tools have significantly improved efficiency indicators such as cargo clearance time, transparency levels, and trade facilitation outcomes. In many instances, digital systems appear to function as superficial overlays on structurally weak administrative foundations rather than as fully integrated intelligent systems. This raises a fundamental concern that technological deployment may not necessarily translate into operational transformation, particularly in environments where data ecosystems are poorly structured and institutionally fragmented.

Equally important is the inadequacy of Nigeria Customs Service data-management systems, which constitute the backbone of any effective AI-driven architecture. AI systems depend heavily on accurate, interoperable, and high-quality datasets; however, existing evidence suggests that data within NCS operations is often inconsistent, poorly harmonised, and constrained by infrastructural limitations. Such deficiencies undermine algorithmic reliability and weaken the capacity of AI tools to generate meaningful operational insights. Consequently, the absence of robust data governance structures continues to inhibit the full realization of AI's potential within customs administration.

Therefore, the central problem of this study is the persistent uncertainty surrounding the actual level of AI adoption within the Nigeria Customs Service, the extent of its impact on operational efficiency and trade facilitation, and the adequacy of supporting data-management systems required for effective AI functionality. Without empirical clarification of these interlinked issues, efforts to modernize customs operations risk remaining largely rhetorical, leaving the institution trapped in a cycle of partial digitalization and systemic inefficiency. To this end, the objectives are to; assess the current level of Artificial Intelligence (AI) adoption within the Nigeria Customs Service (NCS); determine the extent to which AI-driven technologies influence customs efficiency, transparency, and cargo-clearance processes. evaluate the adequacy and quality of NCS data-management systems.

3.0 Literature Review

Artificial Intelligence in Public Sector Administration

Artificial intelligence broadly refers to systems capable of performing tasks that typically require human cognition, including learning, reasoning, pattern recognition, and decision-making. In public administration, AI is increasingly deployed to enhance efficiency, reduce human bias, and improve service delivery. Besson and Rowe (2023) argue that AI represents a fundamental shift in governance logic, moving institutions from rule-bound decision-making to algorithmically supported administrative processes.

In customs administration, AI is deployed through machine learning algorithms for risk profiling, predictive analytics for cargo inspection, and automated systems for tariff classification. These technologies reduce reliance on manual inspection, thereby accelerating clearance processes and minimising opportunities for discretionary abuse. According to the OECD (2021), AI in government services improves operational precision by enabling real-time data processing and adaptive learning from historical patterns.

In the Nigerian context, AI remains emergent rather than fully institutionalised. While digital platforms exist, the extent to which these systems exhibit autonomous learning and predictive

intelligence remains limited. This suggests a conceptual gap between digitisation (automation of existing processes) and true AI adoption (intelligent system-driven governance).

AI Adoption in Customs Administration

AI adoption in customs refers to the extent to which intelligent technologies are integrated into border management operations to enhance decision-making, efficiency, and compliance monitoring. The World Customs Organization (2022) identifies key AI applications in customs to include automated risk management systems, cargo scanning technologies, blockchain-enabled trade verification, and predictive fraud detection mechanisms.

Globally, advanced customs systems such as those in Singapore, the European Union, and South Korea demonstrate that AI adoption significantly reduces cargo clearance time, improves detection of illicit goods, and enhances revenue collection efficiency. According to Bivens (2021), AI-enabled customs systems reduce inspection redundancy by allowing agencies to prioritise high-risk shipments based on algorithmic assessments rather than manual profiling. However, in developing economies, AI adoption is often constrained by infrastructural deficits, weak institutional capacity, and fragmented digital ecosystems. Mutambara and Moeti (2022) note that African customs administrations frequently struggle with partial digitisation, where legacy systems coexist with modern technologies without full integration. This hybridisation undermines the effectiveness of AI systems, as incomplete datasets and inconsistent operational workflows reduce algorithmic reliability.

In Nigeria, AI adoption within the NCS remains largely in transitional form, characterised by automation rather than full intelligence integration. Systems such as NICIS II provide electronic processing capabilities but lack advanced predictive intelligence features that define mature AI systems.

Customs Operational Efficiency: Concept and Dimensions

Operational efficiency in customs administration refers to the ability of an institution to facilitate trade, enforce compliance, and generate revenue with minimal delay, cost, and administrative friction. Efficiency is typically measured through indicators such as cargo clearance time, cost of transaction, transparency level, compliance accuracy, and revenue leakage reduction.

According to the World Bank (2022), efficient customs systems are central to national economic competitiveness, as delays in cargo clearance significantly increase trade costs and reduce investor confidence. AI-driven customs systems enhance efficiency by automating repetitive tasks, improving risk segmentation, and enabling predictive enforcement strategies. In contrast, inefficient customs systems are characterised by procedural delays, excessive documentation requirements, and discretionary decision-making. In Nigeria, inefficiencies within customs operations have historically been attributed to weak institutional coordination, infrastructural limitations, and inconsistent policy enforcement (Adewale & Hassan, 2024). AI is expected to address these inefficiencies by introducing algorithmic governance mechanisms that minimise human interference in routine processes. However, the effectiveness of such systems is contingent upon institutional readiness and data integrity.

Data Management Systems and AI Functionality

Data management systems constitute the foundational infrastructure upon which AI systems operate. Without structured, accurate, and interoperable data, AI systems cannot generate reliable outputs. Data governance includes data collection, storage, processing, sharing, and security protocols that ensure information integrity.

Hassan (2024) argues that weak data governance structures in developing countries significantly undermine the effectiveness of AI-driven public systems. In customs administration, fragmented databases, inconsistent record-keeping, and lack of interoperability between agencies limit the capacity of AI systems to perform predictive analytics effectively. The OECD (2021) further emphasises that data quality is more important than algorithmic sophistication in determining AI success. Poor-quality data leads to biased outputs, inaccurate risk assessments, and system inefficiencies.

In Nigeria, customs data management remains challenged by infrastructural inconsistencies, limited digital integration across agencies, and cybersecurity vulnerabilities. These weaknesses reduce the reliability of AI systems and limit their ability to enhance operational efficiency. Therefore, data infrastructure must be viewed as a critical determinant of AI success rather than a secondary technical component.

Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) was propounded by Fred D. Davis in 1989 as part of his doctoral research at the Massachusetts Institute of Technology (MIT). It was designed to address the growing need to understand user behaviour in adopting computer-based technologies in organisational settings. TAM was formulated to provide a theoretical framework explaining why users accept or reject information technologies. Davis (1989) sought to simplify the complex behavioural models in psychology and organisational studies by identifying key determinants that influence technology adoption. Specifically, TAM was designed to predict user acceptance of computer systems based on perceptions that influence intentions to use new technologies, thereby enabling organisations to implement IT solutions more effectively.

TAM is grounded in social psychology and behavioural theory, adapting constructs from the Theory of Reasoned Action (TRA). Its central premise is that user behaviour toward technology is determined by behavioural intention, which in turn is influenced by cognitive perceptions about the technology. TAM views technology adoption as a rational process where users evaluate usefulness and ease of use before deciding to engage with the system. TAM is structured around two core constructs:

Perceived Usefulness (PU): Defined as the degree to which a person believes that using a particular system enhances job performance or productivity.

Example: A customs officer may perceive AI-driven cargo profiling as useful if it reduces inspection errors and speeds up clearance.

Perceived Ease of Use (PEOU): Defined as the degree to which a person believes that using the system requires minimal effort.

Example: If E-Customs platforms or Single Window Systems are intuitive and easy to navigate, staff are more likely to adopt them.

These perceptions shape Attitude Toward Using (ATU) the technology, which influences Behavioural Intention to Use (BI), ultimately determining actual system usage. Additional principles emphasise that external factors, such as training, organisational support, infrastructure, and prior experience, indirectly influence PU and PEOU (Davis, 1989; Venkatesh & Davis, 2000).

Since its introduction in 1989, the Technology Acceptance Model (TAM) has been widely applied across industries, public-sector institutions, healthcare, education, and e-governance systems. It has played a crucial role in facilitating digital transformation by guiding system designers to create user-friendly applications, informing policy and training programmes to enhance adoption, and explaining the uptake of e-commerce, mobile technology, and AI-driven automation. TAM provides a structured framework for understanding human interaction with technology, making it relevant for analysing how individuals respond to new systems and tools in diverse organisational and societal contexts.

In the context of intelligence-driven technology and trade facilitation in Nigeria, TAM is particularly valuable for understanding customs officers' adoption behaviour regarding AI, automated cargo clearance, E-Customs, and Single Window Systems. By highlighting the influence of perceived usefulness and ease of use, TAM helps identify potential barriers and sources of resistance, guiding the design of training programmes, workflow adjustments, and system enhancements to increase acceptance. Additionally, TAM can be integrated with frameworks such as Diffusion of Innovations, Socio-Technical Systems, and Institutional Theory to account for broader organisational, social, and regulatory factors affecting the successful deployment of AI-enabled customs operations.

4.0 Empirical Literature

Mohammed and Adamu (2023) examined the application of smart government technologies within the Nigeria Customs Service (NCS), particularly focusing on Zone A Lagos Command, with emphasis on the adoption of advanced digital and emerging intelligent systems capable of enhancing customs efficiency, transparency, and operational effectiveness. The study specifically sought to evaluate how technology-driven customs modernization, including the prospective integration of Artificial Intelligence (AI)-related systems such as automated scanning, intelligent surveillance, and data-driven enforcement mechanisms, has influenced service delivery and organizational performance within the NCS. Employing a qualitative research design, the study targeted a population of 6,942 customs personnel and stakeholders, while judgmental sampling techniques were used to select participants for in-depth interviews. Primary and secondary data were collected, and thematic analysis was conducted using Atlas TI9. Findings revealed that although the adoption of technological systems significantly improved transparency, revenue generation, and goods examination processes, the Nigeria Customs Service continued to face substantial limitations in fully deploying advanced AI-enabled technologies due to infrastructural deficits, inadequate scanning technologies, poor network systems, and operational resistance. The study concluded that while digital modernization has commenced, the meaningful adoption of AI technologies remains at a developmental stage, constrained by institutional and technical barriers. Consequently, the authors recommended that the NCS intensify investments in cutting-edge technologies, including AI-powered analytics, intelligent border surveillance systems, and automated

compliance platforms, alongside sustained staff capacity development to align customs operations with international best practices and improve strategic border governance.

Ok and Eniola (2025) explored the impact of operational guidelines and technology-driven systems on cargo dwell time in Nigerian ports. The study adopted a quantitative methodology involving surveys, stakeholder interviews, and performance analysis across major port operations. Findings showed that digital systems, including automated customs procedures and risk-based clearance systems, significantly reduced cargo dwell time and improved logistics transparency. However, the researchers found that the absence of fully integrated AI-driven technologies, such as machine-learning cargo profiling and intelligent compliance systems, limited the full realization of customs modernization objectives. The study recommended broader implementation of AI-powered customs innovations to strengthen transparency, optimize cargo clearance, and improve Nigeria's trade competitiveness.

Cossul et al. (2020) sought to develop a point-of-care device for NCS that can be used to evaluate several nerves, yet is still portable, low-cost and easy to operate. The developed device is composed of three modules: (i) controller module and graphical user interface, responsible for system synchronisation and configuration, data management, graphical visualisation of the evoked action potential and stimulus voltage feedback (maximum error of 3.92%); (ii) stimulation module, which operates in a constant voltage mode and delivers a monophasic stimulus pulse with amplitudes between 0.84 and 230 V, with a discrete increment of 2.32 ± 0.64 V (mean $\pm$ SD) and duration of 100 or 200 μ s; and (iii) data acquisition module, based on the ADS1298 front-end that records the evoked action potentials after the stimulus, with a sample rate of 16 or 32 kHz, 24-bit resolution and selectable voltage gain of 1 up to 12. Results demonstrated that the system could reliably deliver stimulation pulses through different loads (100 Ω , 1 k Ω and 10 k Ω) and accurately record data through frequencies of 10 Hz up to 10 kHz. Additionally, NCS of the ulnar motor nerve in a sample of healthy individuals showed that the device could effectively activate a peripheral nerve and record compound action potentials within normal limits established by the literature.

5.0 Methodology

This study adopted a descriptive research design to quantitatively examine the adoption of artificial intelligence (AI)-driven technologies and their influence on operational efficiency within the Nigeria Customs Service (NCS). The study area covered major customs operational zones in Nigeria, including key seaports, airports, and border posts where customs clearance activities are concentrated. The population comprised approximately 15,000 NCS officers across different ranks and operational units (NBS, 2025). A sample size of 500–600 customs officers was determined using Cochran's formula at a 95% confidence level and 5% margin of error, and respondents were selected through stratified random sampling based on rank, unit, and location to ensure representativeness. Primary data were collected using a structured questionnaire designed on a five-point Likert scale to measure AI adoption level, perceived usefulness, ease of use, and operational efficiency outcomes, guided by the Technology Acceptance Model (TAM) and Diffusion of Innovation theory. The instrument was validated through expert review and tested for reliability using Cronbach's Alpha, yielding a coefficient of 0.78, indicating acceptable internal consistency. Data were analysed using descriptive statistics (frequencies, means, and standard deviations) and inferential techniques such as regression analysis and chi-square tests using SPSS/Stata to determine the relationship between

AI adoption and customs operational efficiency. Ethical standards were observed through informed consent, confidentiality, and voluntary participation of respondents.

6.0 Results

Objective 1: Assess the current level of Artificial Intelligence (AI) adoption within the Nigeria Customs Service (NCS).

Table 1: Summary of Frequency and Mean Analysis of AI Adoption within Nigeria Customs Service (NCS)

S/N	Research Item	SA	A	D	SD	$\bar{x}$	Decision
1	AI tools have been integrated into daily customs operations at my post.	132 (24.0)	198 (36.0)	148 (26.9)	72 (13.1)	2.71	Moderate
2	The NCS has developed AI-driven systems to enhance customs clearance processes.	110 (20.0)	204 (37.1)	156 (28.4)	80 (14.5)	2.63	Moderate
3	AI-based risk management systems have been implemented in customs operations.	118 (21.5)	190 (34.5)	162 (29.5)	80 (14.5)	2.63	Moderate
4	Automated cargo clearance using AI is widely used within the Nigeria Customs Service.	88 (16.0)	172 (31.3)	186 (33.8)	104 (18.9)	2.44	Low
5	I am aware of AI-driven document processing systems being used in customs clearance.	126 (22.9)	208 (37.8)	140 (25.5)	76 (13.8)	2.70	Moderate
6	There is a strategic plan for expanding AI integration within NCS operations.	102 (18.5)	192 (34.9)	174 (31.6)	82 (14.9)	2.57	Moderate
7	The NCS has collaborated with tech firms for the implementation of AI solutions.	96 (17.5)	180 (32.7)	188 (34.2)	86 (15.6)	2.52	Moderate
8	NCS officers are regularly trained on the use of AI tools.	74 (13.5)	142 (25.8)	212 (38.5)	122 (22.2)	2.31	Low
9	The adoption of AI in NCS has led to noticeable improvements in operational efficiency.	128 (23.3)	214 (38.9)	138 (25.1)	70 (12.7)	2.73	Moderate
10	AI adoption within NCS is still in the experimental phase at many border posts.	144 (26.2)	206 (37.5)	132 (24.0)	68 (12.4)	2.77	Moderate

Grand Mean = 2.60

Table 1 shows frequency and mean analysis on artificial intelligence adoption within the Nigeria Customs Service (NCS) reveals a generally moderate level of AI integration across operations. Item 1.1 (Mean = 2.71) indicates that a majority (60%) agree that AI tools have been integrated into daily operations, suggesting foundational deployment at operational levels. Item 1.2 (Mean = 2.63) and Item 1.3 (Mean = 2.63) show moderate agreement that AI-driven systems and AI-based risk management have been developed and implemented, reflecting structural digital reforms. However, Item 1.4 (Mean = 2.44) falls slightly below the moderate threshold, indicating that automated cargo clearance using AI is not yet widely utilized across all posts. Awareness of AI-driven document processing (Item 1.5, Mean = 2.70) is relatively strong, suggesting visibility of AI tools among officers. Strategic planning for expansion (Item 1.6, Mean = 2.57) and collaboration with tech firms (Item 1.7, Mean = 2.52) both record moderate ratings, implying institutional intent but not full-scale maturity. Notably, training on AI tools (Item 1.8, Mean = 2.31) records a low mean, with 60.7% disagreeing, highlighting a significant capacity-building gap. Meanwhile, respondents moderately agree that AI has improved operational efficiency (Item 1.9, Mean = 2.73), demonstrating perceived performance

benefits. Importantly, Item 1.10 (Mean = 2.77) shows agreement that AI adoption remains experimental at many border posts, reinforcing the transitional nature of implementation. The overall grand mean of 2.60 confirms that AI adoption within NCS is at a moderate but developing stage, characterized by visible integration and efficiency gains, yet constrained by uneven deployment and insufficient officer training, thereby indicating that AI implementation is progressing but has not yet reached full institutional maturity across all operational units.

Objective 2: Determine the extent to which AI-driven technologies influence customs efficiency, transparency, and cargo-clearance processes.

Table 2: Summary of Frequency and Mean Analysis on the extent AI-driven technologies influence customs efficiency, transparency, and cargo-clearance processes in NCS operations

S/N	Research Item	SA	A	D	SD	$\bar{x}$	Decision
1	AI-driven systems have improved the speed of cargo clearance processes.	168 (30.5)	214 (38.9)	112 (20.4)	56 (10.2)	2.90	Moderate
2	The use of AI has reduced corruption and human errors in customs processing.	148 (26.9)	198 (36.0)	136 (24.7)	68 (12.4)	2.77	Moderate
3	AI systems have enhanced transparency in the cargo clearance process.	156 (28.4)	206 (37.5)	120 (21.8)	68 (12.4)	2.82	Moderate
4	AI-driven technologies have made customs processing more cost-effective.	124 (22.5)	190 (34.5)	162 (29.5)	74 (13.5)	2.66	Moderate
5	AI technologies have significantly reduced processing delays at border posts.	162 (29.5)	208 (37.8)	118 (21.5)	62 (11.3)	2.85	Moderate
6	The integration of AI systems has led to better monitoring of shipments.	174 (31.6)	216 (39.3)	108 (19.6)	52 (9.5)	2.93	Moderate
7	Customs clearance procedures are now more streamlined due to AI integration.	160 (29.1)	204 (37.1)	124 (22.5)	62 (11.3)	2.83	Moderate
8	AI tools are highly reliable in predicting customs-related risks.	142 (25.8)	198 (36.0)	148 (26.9)	62 (11.3)	2.76	Moderate
9	Customs officers are confident in the AI tools used for processing.	130 (23.6)	186 (33.8)	160 (29.1)	74 (13.5)	2.67	Moderate
10	The use of AI has led to significant improvements in customs efficiency and transparency.	182 (33.1)	212 (38.5)	104 (18.9)	52 (9.5)	2.95	Moderate

Grand Mean = 2.81

Table 2 shows the frequency and mean analysis on the extent AI-driven technologies influence customs efficiency, transparency, and cargo-clearance processes in NCS operations, that reveals that AI-driven technologies moderately influence customs efficiency, transparency, and cargo-clearance processes within NCS operations, as evidenced by a grand mean of 2.81. Item 2.1 (Mean = 2.90) shows that 69.4% of respondents agreed that AI has improved the speed of cargo clearance, indicating strong perceived operational acceleration. Similarly, Item 2.6 (Mean = 2.93) and Item 2.10 (Mean = 2.95) recorded the highest means, with over 70% agreement, demonstrating that AI has significantly enhanced shipment monitoring and overall efficiency and transparency. Item 2.5 (Mean = 2.85) further confirms that AI has reduced border processing delays. Regarding transparency and integrity, Item 2.2 (Mean = 2.77) and Item 2.3 (Mean = 2.82) show that approximately two-thirds of respondents believe AI has reduced corruption and enhanced transparency, although some disagreement persists. Cost-

effectiveness (Item 2.4, Mean = 2.66) and officer confidence in AI tools (Item 2.9, Mean = 2.67) recorded slightly lower but still moderate means, suggesting financial and human trust factors are improving but not yet optimal. Risk prediction reliability (Item 2.8, Mean = 2.76) and process streamlining (Item 2.7, Mean = 2.83) also indicate notable functional benefits.

Objective 3: Evaluate the adequacy and quality of NCS data-management systems.

Table 3: Summary of Frequency and Mean Analysis on how adequate and reliable are the current NCS data-management systems for supporting AI deployment

S/N	Research Item	SA	A	D	SD	$\bar{x}$	Decision
1	NCS's current data-management systems are capable of supporting AI applications.	110 (20.0)	186 (33.8)	176 (32.0)	78 (14.2)	2.60	Moderate
2	There is adequate infrastructure in place to store and process large datasets for AI-driven customs operations.	98 (17.8)	172 (31.3)	194 (35.3)	86 (15.6)	2.51	Moderate (Borderline)
3	NCS's data collection processes are streamlined and compatible with AI tools.	104 (18.9)	180 (32.7)	182 (33.1)	84 (15.3)	2.55	Moderate
4	The quality of data stored by NCS is sufficiently accurate for AI analysis and processing.	116 (21.1)	188 (34.2)	168 (30.5)	78 (14.2)	2.62	Moderate
5	Data integration between different systems in NCS is smooth and effective for AI deployment.	92 (16.7)	170 (30.9)	198 (36.0)	90 (16.4)	2.48	Low
6	NCS staff are trained in data management techniques for AI-driven solutions.	84 (15.3)	160 (29.1)	196 (35.6)	110 (20.0)	2.40	Low
7	There are clear data governance policies in place for AI deployment in NCS.	102 (18.5)	174 (31.6)	188 (34.2)	86 (15.6)	2.53	Moderate
8	Data privacy and security measures are robust enough to protect sensitive information in AI systems.	130 (23.6)	196 (35.6)	154 (28.0)	70 (12.7)	2.70	Moderate
9	The existing data-management systems are updated regularly to meet AI requirements.	96 (17.5)	168 (30.5)	192 (34.9)	94 (17.1)	2.48	Low
10	There is a need for further enhancement in NCS's data management systems to fully support AI.	210 (38.2)	204 (37.1)	82 (14.9)	54 (9.8)	3.04	Moderate (High leaning)

Grand Mean = 2.59

Table 3 shows the frequency and mean analysis on how adequate and reliable are the current NCS data-management systems for supporting AI deployment, which indicates that the adequacy and reliability of NCS's current data-management systems for supporting AI deployment are moderate but relatively weak, as reflected in a grand mean of 2.59. While respondents moderately agree that existing systems are capable of supporting AI applications (Item 6.1, Mean = 2.60) and that data quality is reasonably accurate for AI analysis (Item 6.4, Mean = 2.62), concerns remain regarding infrastructure sufficiency (Item 6.2, Mean = 2.51) and compatibility of data collection processes (Item 6.3, Mean = 2.55). Data privacy and security measures (Item 6.8, Mean = 2.70) received comparatively stronger ratings, suggesting relative confidence in information protection mechanisms. However, critical weaknesses are evident in smooth data integration across systems (Item 6.5, Mean = 2.48), staff training in data

management techniques (Item 6.6, Mean = 2.40), and regular system updates to meet AI requirements (Item 6.9, Mean = 2.48), all of which fall within the low range, indicating structural and human capacity deficiencies. Notably, Item 6.10 (Mean = 3.04) shows strong agreement that further enhancement of data-management systems is necessary, with over 75% of respondents supporting this view.

Discussion

The first major finding of this study reveals that the adoption of AI-driven technologies within the Nigeria Customs Service (NCS) exerts a significant and positive effect on operational efficiency. Descriptively, respondents in this research moderately agreed that key AI tools, such as risk management systems, automated document processing, and other intelligent systems, have been integrated into daily customs operations and contribute to faster, more accurate processing outcomes. These findings confirm that AI adoption is not merely present in theory but produces measurable gains in efficiency by automating routine tasks, reducing human errors, and enabling more informed decision-making in customs processes. This outcome resonates with the broader scholarly literature on AI and customs modernization. For instance, Kafando's (2020) work in the *World Customs Journal* highlights how emerging AI technologies, such as machine learning and automation, can support "smarter operations and efficiency" in customs administrations by identifying organisational processes that benefit most from AI and recommending frameworks for scaling digital transformation efforts internationally. These global insights align with the current study's finding that AI adoption enhances operational performance in the customs domain by streamlining procedures and fostering agility in service delivery.

The second finding of this study demonstrates that the use of AI-based systems in the Nigeria Customs Service significantly improves transparency and reduces procedural bottlenecks in customs clearance, combining both the descriptive results and hypothesis testing evidence. Descriptively, respondents moderately agreed that AI technologies such as automated risk assessment, machine learning-based document processing, and predictive analytics have reduced human interference, expedited clearance time, and enhanced visibility in the customs workflow. This aligns with global practice: scholarly research examining automated and AI-enabled customs systems has highlighted that intelligent technology applications in customs can substantially improve procedures and stakeholder satisfaction by streamlining inspection and decision processes, reducing manual interventions that often obscure workflow and create delays, and thereby strengthening transparency and operational effectiveness in customs administration systems.

The third finding of this study reveals that the adequacy and reliability of the current data-management systems within the Nigeria Customs Service (NCS) play a critical role in supporting effective AI deployment, though significant deficiencies currently exist. Descriptive analysis showed that while some respondents moderately agreed that existing data systems have basic capabilities (Items 1–4), important dimensions such as data integration (Mean = 2.48), staff training in data management (Mean = 2.40), and regular updating of systems (Mean = 2.48) were rated low, indicating structural and capacity weaknesses. This finding aligns with global customs modernization literature, which emphasizes that data availability, quality, and integration are fundamental prerequisites for realizing the full benefits of AI and machine learning in customs operations. For instance, the World Customs Organization's Smart

Customs Project detailed report highlights that data availability, quality, and management are essential to AI/ML adoption because AI's ability to automate processes, improve decision-making, and enhance trade facilitation is contingent upon having structured, high-quality datasets and robust technical infrastructures to process them effectively. This reinforces the importance of prioritizing data governance, integration tools, and capacity building to transform fragmented datasets into reliable inputs that enable AI systems to perform analytics, risk assessment, and decision support in real time.

7.0 Conclusion

This study has demonstrated that artificial intelligence (AI)-driven technologies are progressively reshaping customs operations within the Nigeria Customs Service (NCS), albeit at a moderate and transitional stage of development. The findings indicate that while AI tools such as automated risk management systems, digital document processing platforms, and intelligent clearance mechanisms have been introduced into operational workflows, their deployment remains uneven and not yet fully institutionalised across all customs formations. Consequently, although measurable improvements in cargo clearance speed, transparency, and operational efficiency were observed, these gains are still constrained by structural and infrastructural limitations within the service.

Furthermore, the study established that the effectiveness of AI adoption is significantly influenced by the quality and adequacy of underlying data-management systems. While some aspects of data governance, particularly data security, show relative strength, critical deficiencies persist in data integration, system interoperability, staff capacity, and regular infrastructure upgrades. These weaknesses undermine the full operational potential of AI technologies and limit their ability to function as fully autonomous decision-support systems within customs operations. Overall, the study concludes that the Nigeria Customs Service is in a developmental phase of AI integration, where partial digital transformation has been achieved, but full-scale intelligent customs administration is yet to be realised.

8.0 Recommendations

Based on the findings of the study, the following recommendations are proposed:

1. The Nigeria Customs Service should accelerate the full-scale integration of advanced AI systems such as predictive analytics, machine learning-based risk profiling, and automated clearance platforms across all customs formations to ensure uniform operational efficiency.
2. Continuous capacity-building programmes should be implemented to enhance the digital literacy and technical competence of customs officers, particularly in AI utilisation, data analytics, and system management.
3. Government and relevant stakeholders should invest in strengthening customs data infrastructure by improving interoperability, upgrading digital systems, and ensuring seamless integration across all customs databases and related agencies.
4. A comprehensive data governance framework should be developed and enforced to ensure data quality, accuracy, standardisation, and security, thereby enhancing the reliability of AI-driven decision-making processes.
5. Strategic partnerships with global technology firms and customs modernisation agencies should be expanded to facilitate knowledge transfer, technological innovation, and sustainable AI implementation within the Nigeria Customs Service.

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