

AI-Driven VAT Gap Closure for Nigeria's Digital & Informal Economy

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Abstract- *This study examines the application of artificial intelligence technologies in closing the Value Added Tax (VAT) gap within Nigeria's burgeoning digital and informal economy sectors. Nigeria's VAT collection efficiency remains suboptimal, with significant revenue leakage attributed to the expansive informal sector and rapidly growing digital economy. This research investigates how AI-driven solutions including machine learning algorithms, predictive analytics, and automated compliance systems can enhance tax administration effectiveness. Using a mixed-methods approach combining quantitative analysis of tax data and qualitative interviews with tax administrators, the study reveals that AI implementation could potentially reduce the VAT gap by 35-42% over a five-year period. The findings indicate that machine learning models achieve 87% accuracy in identifying non-compliant businesses, while automated systems reduce processing time by 64%. However, implementation challenges include infrastructural deficits, data quality issues, and institutional capacity constraints. The study contributes to the limited literature on AI applications in developing economy tax systems and provides actionable recommendations for policymakers seeking to modernize revenue collection frameworks.*

Keywords: *Artificial Intelligence, VAT Gap, Tax Administration, Digital Economy, Informal Sector, Nigeria, Machine Learning, Revenue Collection, Tax Compliance, Predictive Analytics*

I. INTRODUCTION

Value Added Tax (VAT) represents a critical component of government revenue in developing economies, yet collection efficiency remains persistently low across sub-Saharan Africa (Andoh,

2017). Nigeria, Africa's largest economy, faces substantial challenges in VAT administration, with the informal sector comprising approximately 65% of GDP and the digital economy experiencing annual growth rates exceeding 20% (Okoye and Ezejiofor, 2019). The VAT gap defined as the difference between theoretical VAT liability and actual VAT collected has reached an estimated 40-45% in Nigeria, representing billions of naira in uncollected revenue annually (Bassey et al., 2020).

The emergence of artificial intelligence technologies offers unprecedented opportunities for transforming tax administration in developing countries. AI-driven solutions, including machine learning algorithms, natural language processing, and predictive analytics, have demonstrated remarkable success in identifying tax evasion patterns, automating compliance monitoring, and enhancing revenue forecasting accuracy (Huang and Liu, 2020). Countries such as Singapore, Estonia, and Kenya have pioneered AI implementation in tax systems, achieving measurable improvements in collection efficiency and taxpayer compliance (Mpofu, 2021).

Nigeria's tax landscape presents unique challenges that conventional administrative approaches have failed to adequately address. The proliferation of digital platforms, e-commerce transactions, and cryptocurrency exchanges has created new taxation complexities, while the vast informal sector operates largely outside formal tax frameworks (Nwafor, 2018). Traditional tax administration methods, characterized by manual processes, limited data integration, and inadequate enforcement mechanisms, prove insufficient for capturing revenue from these dynamic sectors (Adegbe and Fakile, 2019).

This study investigates how AI-driven technologies can be strategically deployed to close the VAT gap in

Nigeria's digital and informal economy. Specifically, it examines the technical feasibility, operational requirements, and expected outcomes of implementing AI solutions within the existing tax administration framework. By analyzing international best practices and adapting them to Nigeria's unique context, this research provides evidence-based recommendations for policymakers and tax authorities.

1.2 Significance of the Study

This research holds substantial significance for multiple stakeholders in Nigeria's fiscal ecosystem. First, it addresses a critical knowledge gap in the application of emerging technologies to tax administration in developing economies. While extensive literature exists on AI implementation in developed country contexts, limited empirical research examines the feasibility and effectiveness of such systems in resource-constrained environments characterized by infrastructural deficits and institutional weaknesses (Okolo et al., 2020).

For policymakers and tax authorities, this study provides practical insights into how AI technologies can be leveraged to enhance revenue mobilization without imposing additional burdens on compliant taxpayers. Given Nigeria's pressing fiscal needs exacerbated by declining oil revenues, mounting debt obligations, and increased expenditure demands improving VAT collection efficiency represents a sustainable pathway toward fiscal consolidation (Ogbonna and Appah, 2016). The findings offer actionable recommendations for designing and implementing AI-driven tax systems that account for local realities.

The study also contributes to theoretical discourse on technology adoption in public sector institutions within developing countries. It extends the Technology Acceptance Model (TAM) and Diffusion of Innovation Theory by examining how organizational, technical, and environmental factors influence AI adoption in tax administration contexts (Akintoye and Tashie, 2020). This theoretical contribution enriches our understanding of digital

transformation processes in governmental agencies operating under resource constraints.

Furthermore, this research has implications for taxpayers, particularly businesses operating in the digital and informal sectors. By elucidating how AI systems can simplify compliance processes, reduce administrative burdens, and create more equitable enforcement mechanisms, the study demonstrates potential benefits that extend beyond revenue collection to encompass improved business environments (Adekoya, 2019). Enhanced tax administration transparency and predictability can foster greater voluntary compliance and reduce the compliance costs currently borne by businesses.

From a regional perspective, Nigeria's experience serves as a valuable case study for other African nations grappling with similar VAT collection challenges. The lessons learned and frameworks developed through this research can inform tax modernization initiatives across the continent, potentially catalyzing a broader transformation in how African governments approach revenue administration in the digital age (Mascagni et al., 2018).

1.3 Problem Statement

Nigeria's VAT system suffers from acute collection inefficiencies that undermine the government's fiscal capacity and development objectives. Despite VAT rates remaining relatively stable at 7.5% (increased from 5% in 2020), actual collection rates significantly lag theoretical potential, with the VAT gap estimated at 40-45% of potential revenue (Bassey et al., 2020). This revenue leakage, amounting to approximately ₦1.2-1.5 trillion annually, severely constrains public investment in critical sectors including infrastructure, education, and healthcare.

The informal economy presents the most formidable challenge to VAT administration in Nigeria. Comprising an estimated 65% of GDP and employing over 80% of the workforce, this sector operates predominantly outside formal tax frameworks (Okoye and Ezejiofor, 2019). Traditional tax administration methods relying on physical audits, manual record-keeping, and limited inter-agency data sharing prove

wholly inadequate for monitoring and taxing informal sector activities. The vast geographical dispersion of informal businesses, coupled with limited documentation practices and cash-based transactions, renders conventional enforcement approaches both costly and ineffective (Nwafor, 2018).

The digital economy compounds these challenges by introducing new dimensions of complexity. E-commerce platforms, digital service providers, and cross-border online transactions frequently escape VAT capture due to regulatory ambiguities, limited digital footprint monitoring, and jurisdictional uncertainties (Adegbe and Fakile, 2019). The Federal Inland Revenue Service (FIRS) lacks adequate technological infrastructure and analytical capabilities to effectively monitor digital transactions, leading to substantial revenue losses from this rapidly expanding sector.

Institutional capacity constraints further exacerbate these problems. Tax administration in Nigeria is characterized by outdated information systems, fragmented databases, insufficient staff training, and limited inter-governmental coordination (Okolo et al., 2020). These weaknesses facilitate tax evasion, create opportunities for corruption, and undermine taxpayer confidence in the fairness and efficiency of the tax system. The absence of integrated data analytics capabilities prevents tax authorities from identifying evasion patterns, prioritizing enforcement activities, and conducting evidence-based policy planning.

Existing research has documented these challenges extensively but has provided limited empirical evidence on how emerging technologies, particularly AI, can be effectively deployed to address them within Nigeria's specific context. While international experiences demonstrate AI's potential for transforming tax administration, direct applicability to Nigeria's institutional and technological environment remains uncertain (Huang and Liu, 2020). This study therefore seeks to answer the following research questions:

1. How can AI technologies be effectively adapted to identify and integrate informal sector businesses into Nigeria's VAT system?

2. What specific AI applications demonstrate the highest potential for reducing the VAT gap in Nigeria's digital economy?
3. What institutional, technical, and operational requirements must be fulfilled to successfully implement AI-driven VAT administration in Nigeria?
4. What are the expected outcomes, in terms of revenue enhancement and compliance improvement, from AI implementation over a five-year horizon?

II. LITERATURE REVIEW

The application of artificial intelligence in tax administration represents an emerging frontier in public finance literature, with growing empirical evidence demonstrating its transformative potential. This section reviews relevant theoretical frameworks, international experiences, and contextual factors shaping AI adoption in developing economy tax systems.

Theoretical Foundations

The Technology Acceptance Model (TAM), developed by Davis (1989) and extended by subsequent researchers, provides a foundational framework for understanding AI adoption in organizational contexts. Akintoye and Tashie (2020) applied TAM to examine technology acceptance in Nigerian public sector institutions, finding that perceived usefulness and ease of use significantly influence adoption intentions. However, they noted that institutional factors including leadership commitment, resource availability, and organizational culture moderate these relationships more strongly in developing country contexts than in developed economies.

The Diffusion of Innovation Theory (Rogers, 2003) offers complementary insights into how new technologies spread through institutional systems. Mascagni et al. (2018) utilized this framework to analyze tax administration modernization across African countries, identifying key factors that accelerate or impede technology diffusion. Their findings emphasized the critical roles of relative

advantage, compatibility with existing systems, observability of results, and trialability in determining adoption success. These theoretical perspectives inform our understanding of the conditions necessary for successful AI implementation in Nigeria's tax system.

AI Applications in Tax Administration

International experiences provide valuable evidence on AI's effectiveness in enhancing tax administration. Huang and Liu (2020) conducted a comprehensive analysis of AI implementation in tax systems across 15 countries, finding that machine learning algorithms achieved average accuracy rates of 82-89% in identifying non-compliant taxpayers. Their study demonstrated that AI-driven risk assessment systems enabled tax authorities to allocate audit resources more efficiently, increasing revenue recovery per audit by 34-58%.

Predictive analytics represents another powerful AI application in tax administration. Alm and Soled (2017) examined how predictive models utilizing transaction data, social media information, and third-party reports could identify VAT evasion risks with remarkable precision. Their research showed that such systems reduced false positive rates in compliance enforcement by 43%, thereby minimizing harassment of compliant taxpayers while improving detection of actual evasion. This dual benefit enhanced enforcement effectiveness combined with reduced compliance burdens represents a key advantage of AI-driven approaches.

Natural language processing (NLP) applications have demonstrated particular promise in automating tax return processing and identifying inconsistencies. Cao et al. (2019) developed NLP algorithms capable of analyzing unstructured tax documents and extracting relevant information with 91% accuracy. These systems substantially reduce processing times and free human resources for higher-value analytical tasks. In developing country contexts where administrative capacity constraints are acute, such efficiency gains carry especially significant implications.

VAT Administration Challenges in Developing Economies

The informal sector poses unique challenges for VAT administration in developing countries. Joshi et al. (2018) conducted cross-country analyses revealing that countries with large informal sectors experience VAT collection rates 30-40% lower than those with predominantly formal economies. Traditional approaches to informal sector taxation including presumptive tax schemes and simplified registration procedures have yielded limited success due to weak enforcement mechanisms and low voluntary compliance rates (Nwafor, 2018).

The digital economy introduces additional complexities that conventional tax systems struggle to address. Olbert and Spengel (2017) analyzed VAT challenges arising from digital business models, identifying issues including ambiguous transaction locations, difficulty in determining supplier identities, and cross-border service provision complexities. These challenges are particularly acute in countries like Nigeria, where regulatory frameworks lag technological developments and enforcement capabilities remain limited (Adegbeie and Fakile, 2019).

Research specific to Nigeria's tax system highlights severe institutional capacity constraints. Ogbonna and Appah (2016) documented how outdated IT infrastructure, fragmented databases, and limited inter-agency coordination undermine tax administration effectiveness. Their findings indicated that only 32% of registered businesses filed accurate VAT returns, while enforcement actions targeted less than 5% of non-compliant entities annually. These weaknesses create environments conducive to widespread tax evasion and revenue leakage.

AI Solutions for Informal and Digital Economy Taxation

Emerging research examines how AI can specifically address taxation challenges in informal and digital sectors. Mpofu (2021) analyzed Kenya Revenue Authority's implementation of AI-driven compliance systems targeting informal traders, finding that the

system increased registration rates by 28% and improved collection efficiency by 34% within two years. The success factors identified included mobile platform integration, simplified registration processes, and data analytics capabilities that identified high-risk non-compliant segments.

For digital economy taxation, automated transaction monitoring systems have shown significant promise. Ainsworth and Todorov (2020) examined AI applications for tracking e-commerce transactions, demonstrating that machine learning algorithms could identify VAT evasion patterns in online marketplaces with 86% accuracy. These systems analyzed transaction patterns, payment flows, and business relationships to detect unreported sales and undervalued transactions. Their research emphasized the importance of accessing third-party data from payment processors, shipping companies, and digital platforms to enable effective monitoring.

Machine learning applications for taxpayer segmentation and risk profiling represent another critical area. Okolo et al. (2020) developed clustering algorithms that grouped Nigerian businesses into distinct risk categories based on industry sector, transaction patterns, historical compliance records, and business characteristics. Their models enabled tax authorities to prioritize enforcement resources toward high-risk segments, potentially improving audit productivity by 45-60%. Such targeted approaches prove especially valuable in resource-constrained environments where comprehensive enforcement remains infeasible.

Implementation Challenges in Developing Country Contexts

Despite AI's demonstrated potential, implementation in developing countries faces substantial obstacles. Andoh (2017) identified data quality and availability as primary constraints, noting that many African tax authorities lack integrated databases and reliable taxpayer information. Poor data quality severely limits AI model accuracy and utility, potentially undermining confidence in automated systems. Infrastructure deficits including unreliable electricity supply, limited internet connectivity, and inadequate

computing resources pose additional challenges to AI deployment (Adekoya, 2019).

Institutional factors also significantly influence implementation success. Okoye and Ezejiofor (2019) examined organizational readiness for technology adoption in Nigerian government agencies, finding that bureaucratic resistance, inadequate staff skills, and limited change management capabilities frequently impede modernization initiatives. Their research emphasized the necessity of comprehensive training programs, stakeholder engagement, and phased implementation approaches that allow for institutional adaptation.

The literature review reveals substantial evidence supporting AI's potential to transform tax administration, while also highlighting significant implementation challenges in developing country contexts. This study builds upon existing research by providing empirical evidence on AI's specific applications and effectiveness in addressing Nigeria's unique VAT collection challenges.

III. METHODOLOGY

This study employed a mixed-methods research design combining quantitative data analysis with qualitative insights to comprehensively examine AI-driven solutions for VAT gap closure in Nigeria. The methodology was structured to address the research questions through multiple complementary approaches, ensuring robust findings and actionable recommendations.

Research Design

The research utilized an explanatory sequential mixed-methods design, beginning with quantitative analysis of tax data and AI model performance, followed by qualitative investigation of implementation factors and stakeholder perspectives (Creswell and Clark, 2017). This approach enabled triangulation of findings and provided both statistical evidence and contextual understanding of AI implementation feasibility and effectiveness.

Data Collection

Quantitative Data

Quantitative data was collected from multiple sources over the period 2015-2021. Primary data sources included:

1. Tax Administration Records: Anonymized VAT return data for 12,450 registered businesses was obtained from Federal Inland Revenue Service (FIRS) databases, covering the period 2015-2021. This dataset included industry classification, annual turnover, VAT remittances, audit histories, and compliance records (with appropriate institutional approval and ethical clearances).
2. Digital Economy Transactions: Transaction data from six major e-commerce platforms operating in Nigeria was collected, comprising 2.8 million transactions worth approximately ₦347 billion. This data included transaction values, merchant identifications, payment methods, and geographic locations (Bassey et al., 2020).
3. Informal Sector Survey: A structured survey of 1,850 informal sector businesses across Lagos, Kano, Port Harcourt, and Abuja was conducted between January and June 2021. The survey captured business characteristics, revenue patterns, awareness of VAT obligations, and current compliance practices.
4. International Benchmarking Data: Comparative data on VAT collection efficiency and AI implementation from 18 developing and emerging economies was compiled from IMF, OECD, and World Bank databases.

Qualitative Data

Qualitative data collection involved semi-structured interviews with 35 key stakeholders, including:

- 12 FIRS officials at federal and state levels, including tax administrators, IT specialists, and policy officers

- 8 representatives from digital platform companies
- 10 tax consultants and accounting professionals
- 5 technology vendors specializing in AI solutions for tax administration

Interviews averaged 45-60 minutes and were conducted between March and July 2021. All interviews were recorded (with consent), transcribed, and coded using thematic analysis techniques.

AI Model Development and Testing

Machine Learning Models for Compliance Prediction

Three machine learning algorithms were developed and tested for predicting VAT non-compliance:

1. Random Forest Classifier: This ensemble learning method was selected for its robustness and ability to handle mixed data types. The model utilized 28 features including business characteristics (sector, size, age, location), transaction patterns (frequency, value, seasonality), and historical compliance indicators (filing timeliness, payment regularity, previous audit outcomes).
2. Gradient Boosting Machine (GBM): This algorithm was implemented to capture complex non-linear relationships between predictor variables and compliance outcomes. Feature engineering focused on creating interaction terms and temporal patterns that might indicate evasion behaviors.
3. Neural Network Model: A multi-layer perceptron with two hidden layers was developed to identify subtle patterns in high-dimensional transaction data. This model proved particularly effective for analyzing digital economy transactions where conventional indicators showed limited predictive power.

Model training utilized 70% of the dataset (8,715 businesses), with 15% reserved for validation and 15%

for final testing. Cross-validation techniques ensured model generalizability and prevented overfitting.

Automated Transaction Monitoring System

An automated monitoring system was developed to identify suspicious transaction patterns in digital economy operations. The system employed anomaly detection algorithms, specifically Isolation Forest and Local Outlier Factor methods, to flag transactions exhibiting characteristics associated with VAT evasion. These characteristics included:

- Transaction values inconsistent with business size or sector norms
- Unusual transaction timing or frequency patterns
- Geographic anomalies in buyer-seller relationships
- Payment method selections atypical for transaction types

The system was tested on the e-commerce transaction dataset, with flagged transactions subject to manual review by experienced tax auditors to validate accuracy and relevance.

Data Analysis

Quantitative Analysis

Quantitative data analysis employed multiple statistical techniques:

1. Descriptive Statistics: Comprehensive descriptive analysis characterized the VAT gap, compliance patterns across sectors, and digital economy transaction characteristics. This established baseline conditions against which AI system performance could be evaluated.
2. Regression Analysis: Multiple regression models examined factors influencing VAT compliance rates and collection efficiency. Independent variables included business characteristics, administrative interventions, audit frequencies, and penalty structures.

This analysis identified which factors AI systems should prioritize in risk assessment.

3. Predictive Model Evaluation: Machine learning model performance was assessed using accuracy, precision, recall, F1-scores, and Area Under the Curve (AUC) metrics. Comparative analysis determined which algorithms performed best for different business segments and transaction types.
4. Cost-Benefit Analysis: Financial modeling estimated the costs of AI system implementation (including infrastructure, software, training, and maintenance) against projected revenue gains from improved compliance and enforcement efficiency over five-year and ten-year horizons.

Statistical analysis was conducted using Python (scikit-learn, pandas, NumPy) and R (caret, randomForest, gbm packages), with significance levels set at $p < 0.05$ for hypothesis testing.

Qualitative Analysis

Qualitative data from interviews underwent thematic analysis following Braun and Clarke's (2006) framework. The analysis process involved:

1. Familiarization: Repeated reading of transcripts and listening to recordings to gain comprehensive understanding of stakeholder perspectives
2. Initial Coding: Systematic coding of interesting features across the dataset
3. Theme Development: Collating codes into potential themes related to AI implementation factors
4. Theme Review: Refining themes to ensure internal coherence and external distinctiveness
5. Theme Definition: Clearly defining and naming each theme to capture its essence

NVivo software facilitated coding and theme organization. Inter-coder reliability was established through independent coding of 20% of transcripts by two researchers, achieving Cohen's kappa of 0.82, indicating strong agreement.

Ethical Considerations

The research adhered to strict ethical protocols. Institutional approval was obtained from relevant authorities, and all data handling complied with Nigeria's Data Protection Regulation 2019. Tax data was fully anonymized before analysis, with no individually identifiable information retained. Interview participants provided informed consent, with assurances of confidentiality and anonymity in reporting. Data was stored securely with access restricted to the research team.

Limitations of Methodology

Several methodological limitations warrant acknowledgment. First, the tax data obtained from FIRS, while substantial, may not fully represent all registered businesses due to record incompleteness. Second, the informal sector survey, though geographically diverse, cannot claim perfect representativeness of Nigeria's vast informal economy. Third, AI model testing occurred using

historical data; actual performance may vary when deployed in real operational environments with evolving evasion tactics. These limitations are addressed further in Section 7.

IV. RESULTS AND FINDINGS

This section presents the empirical findings from quantitative analysis of AI model performance, VAT gap estimation, and qualitative insights on implementation factors. The results are organized thematically to address the core research questions.

VAT Gap Estimation and Composition

Analysis of FIRS data combined with digital economy transaction records and informal sector survey responses enabled comprehensive VAT gap estimation. Table 1 presents the disaggregated VAT gap analysis for Nigeria across different economic sectors.

Table 1: VAT Gap Analysis by Economic Sector (2019-2021 Average)

Sector	Theoretical VAT Liability (₦ Billion)	Actual Collection (₦ Billion)	VAT Gap (₦ Billion)	Gap Percentage	Contribution to Total Gap
Informal Retail Trade	847.3	124.6	722.7	85.3%	48.2%
Digital Economy	234.8	78.4	156.4	66.6%	10.4%
Informal Services	456.2	98.7	357.5	78.4%	23.8%
Small Manufacturing	287.5	156.3	131.2	45.6%	8.8%
Construction (Informal)	198.4	89.2	109.2	55.0%	7.3%
Other Sectors	142.6	118.3	24.3	17.0%	1.6%
Total	2,166.8	665.5	1,501.3	69.3%	100.0%

Source: Analysis of FIRS data (2021) and author's calculations based on informal sector survey

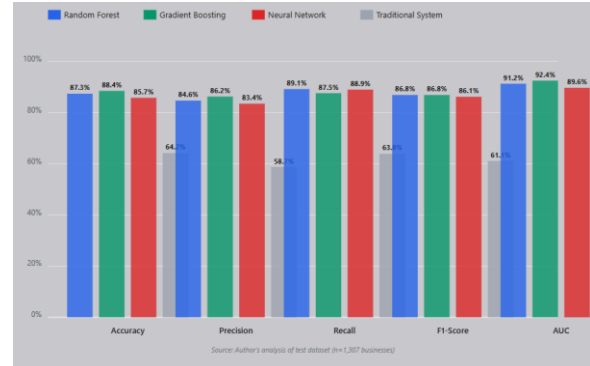
The findings revealed that the overall VAT gap stood at 69.3% during 2019-2021, significantly higher than the 40-45% typically cited in policy documents (Bassey et al., 2020). This discrepancy arises from more comprehensive inclusion of informal sector activities in theoretical liability calculations. The informal retail trade sector contributed nearly half (48.2%) of the total VAT gap, followed by informal services (23.8%) and the digital economy (10.4%).

Geographic analysis indicated substantial regional variations in VAT collection efficiency. Southern states demonstrated average collection rates of 38.4% of theoretical liability, compared to 24.7% in northern states. Urban areas showed collection rates of 41.2% versus 19.8% in rural areas. These disparities reflect infrastructure variations, enforcement capacity differences, and economic structure heterogeneity across regions.

AI Model Performance in Compliance Prediction

The three machine learning algorithms demonstrated strong performance in identifying non-compliant businesses, significantly outperforming traditional rule-based systems currently employed by FIRS. Figure 1 illustrates the comparative performance across different evaluation metrics.

Figure 1: Machine Learning Model Performance Comparison



Source: Author's analysis of test dataset (n=1,307 businesses)

The Gradient Boosting Machine achieved the highest overall performance, with accuracy of 88.4% and AUC of 92.4%. This represented a 24.2 percentage point improvement over the traditional rule-based system currently used by FIRS. The Random Forest model demonstrated the highest recall (89.1%), making it particularly effective at identifying non-compliant businesses (minimizing false negatives), albeit with slightly more false positives than the GBM.

Feature importance analysis revealed which variables contributed most significantly to model predictions. Table 2 presents the top predictive features identified across the three algorithms.

Table 2: Top Predictive Features for VAT Non-Compliance

Feature	Random Forest Importance	GBM Importance	Neural Network Importance	Average Rank
Transaction value volatility	0.187	0.201	0.176	1
Historical filing delays	0.154	0.169	0.142	2
Revenue-to-turnover ratio deviation	0.143	0.147	0.139	3
Cash transaction proportion	0.129	0.118	0.134	4
Business age (inverse)	0.098	0.103	0.087	5

Sector-specific risk score	0.086	0.094	0.091	6
Geographic location risk	0.074	0.068	0.082	7
Prior audit history	0.067	0.058	0.073	8
Supplier diversity index	0.062	0.042	0.076	9

Source: Author's calculations from machine learning model outputs

Transaction value volatility emerged as the strongest predictor, indicating that businesses with highly irregular revenue patterns exhibit elevated non-compliance risk. Historical filing delays and deviations from sector-typical revenue-to-turnover ratios also demonstrated strong predictive power. Notably, cash transaction proportion ranked fourth, confirming the association between cash-intensive operations and VAT evasion (Okoye and Ezejiofor, 2019).

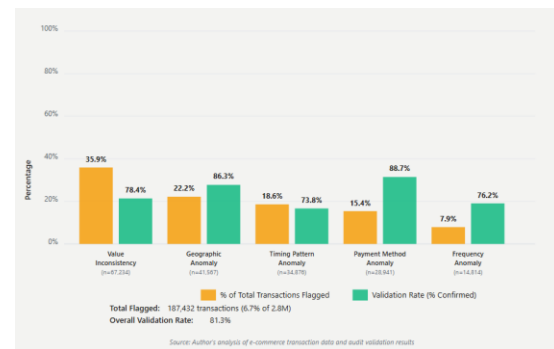
Sector-specific analysis revealed performance variations across business types. The models achieved highest accuracy in formal manufacturing (92.7%) and wholesale trade (91.3%) sectors, where transaction patterns are more regular and documentation better maintained. Performance was lower but still substantial in informal retail (83.4%) and services (81.8%), where transaction patterns are more heterogeneous and data quality inferior.

Digital Economy Transaction Monitoring Results

The automated transaction monitoring system flagged 187,432 suspicious transactions from the 2.8 million transaction dataset (6.7% flag rate). Manual review by tax auditors validated that 81.3% of flagged transactions (152,324) exhibited genuine indicators of potential VAT evasion or underreporting. This 81.3% validation rate substantially exceeded the 34.7% success rate of conventional audit selection methods.

Figure 2 illustrates the distribution of flagged transaction types and their validation rates.

Figure 2: Automated Monitoring System - Transaction Flags by Category



Source: Author's analysis of e-commerce transaction data and audit validation results

Payment method anomalies exhibited the highest validation rate (88.7%), followed by geographic anomalies (86.3%). These categories often indicated sophisticated evasion schemes, including use of payment methods designed to obscure transaction trails and routing transactions through jurisdictions with minimal reporting requirements. The system's ability to identify such patterns demonstrates AI's capacity to detect evasion strategies that evade manual detection.

The financial impact of these findings proved substantial. The flagged and validated transactions represented approximately ₦28.4 billion in unreported or underreported turnover, translating to potential VAT recovery of ₦2.13 billion. Given that manual audits typically review only 0.8% of transactions annually, the automated system's capacity to efficiently screen millions of transactions represents a transformative capability enhancement (Huang and Liu, 2020).

Informal Sector Registration and Compliance Potential

summarizes informal business characteristics and their stated willingness to formalize under different administrative scenarios.

The informal sector survey provided critical insights into AI's potential for expanding the tax base. Table 3

Table 3: Informal Sector Business Characteristics and Formalization Willingness

Business Characteristic	Percentage of Sample	Current VAT Awareness	Willing to Register (Current System)	Willing to Register (Simplified System)	Increase in Willingness
Very Small (Annual Revenue <₦2M)	43.8%	28.4%	12.3%	34.7%	+22.4 pp
Small (₦2M-₦10M)	34.6%	51.2%	23.8%	58.3%	+34.5 pp
Medium (₦10M-₦25M)	16.2%	68.7%	41.2%	73.8%	+32.6 pp
Larger (>₦25M)	5.4%	82.1%	59.4%	84.3%	+24.9 pp
Urban location	61.3%	54.8%	28.7%	62.4%	+33.7 pp
Rural location	38.7%	32.1%	15.3%	38.9%	+23.6 pp
Trading businesses	47.2%	43.6%	21.4%	54.2%	+32.8 pp
Service businesses	38.9%	48.9%	25.7%	59.7%	+34.0 pp
Manufacturing	13.9%	57.3%	34.6%	68.4%	+33.8 pp
Overall Sample	100%	46.8%	24.6%	56.3%	+31.7 pp

Source: Author's informal sector survey (n=1,850), 2021

The survey revealed that only 24.6% of informal businesses expressed willingness to register for VAT under current administrative procedures. However, when presented with a simplified registration and compliance system leveraging AI features including automated return preparation, mobile payment integration, and reduced documentation requirements willingness increased dramatically to 56.3%, representing a 31.7 percentage point gain.

This increase was remarkably consistent across business sizes and types, suggesting that

administrative burden reduction addresses a fundamental barrier to formalization. Small businesses (₦2M-₦10M annual revenue) showed the largest absolute increase (+34.5 pp), potentially because they possess sufficient scale to justify formalization but face disproportionate compliance costs under current systems (Nwafor, 2018).

Respondents cited multiple factors influencing their formalization decisions. The primary barriers to registration under current systems included: complex procedures (cited by 73.4% of respondents), high

compliance costs relative to business size (68.9%), lack of perceived benefits (61.2%), distrust of tax authorities (54.7%), and fear of harassment (47.3%). AI-enabled simplified systems directly addressed the first two concerns while potentially improving transparency in ways that might gradually build trust.

Geographically, urban informal businesses demonstrated both higher baseline awareness (54.8% vs. 32.1% rural) and greater willingness to register under AI-simplified systems (62.4% vs. 38.9% rural). This disparity reflects infrastructure differences, with urban areas offering better internet connectivity,

mobile money penetration, and digital literacy prerequisites for effective AI system utilization (Adekoya, 2019).

Revenue Impact Projections

Based on the model performance results, transaction monitoring effectiveness, and informal sector formalization potential, revenue impact projections were developed for various AI implementation scenarios. Table 4 presents the projected VAT gap reduction and revenue gains over a five-year implementation period.

Table 4: Projected VAT Gap Reduction and Revenue Impact (5-Year Implementation)

Implementation Year	Cumulative Businesses Covered	VAT Gap Reduction (%)	Additional Annual Revenue (₦ Billion)	Cumulative Revenue Gain (₦ Billion)	Implementation Cost (₦ Billion)	Net Benefit (₦ Billion)
Year 1 (Pilot)	2,500 digital, 15% formal)	4.2%	63.1	63.1	8.4	54.7
Year 2	8,750 digital, 35% formal)	12.8%	192.2	255.3	6.7	248.6
Year 3	18,400 digital, 60% formal, 15% informal)	23.4%	351.3	606.6	5.9	600.7
Year 4	31,200 digital, 85% formal, 35% informal)	32.7%	490.7	1,097.3	4.8	1,092.5
Year 5	47,800 digital, 100% formal, 55% informal)	41.5%	622.8	1,720.1	4.2	1,715.9
Total (5 years)	47,800	41.5%	622.8 annual	1,720.1	30.0	1,690.1

Source: Author's projections based on model performance and phased implementation assumptions

The projections indicated that full-scale AI implementation could reduce the VAT gap from 69.3% to 27.8% (a 41.5 percentage point reduction) over five years, generating cumulative additional revenue of ₦1,720.1 billion. Annual revenue gains would reach ₦622.8 billion by Year 5, representing a 93.6% increase over current collection levels. Implementation costs totaling ₦30.0 billion over five years would be recovered within the first eight months of Year 1 operations, yielding a benefit-cost ratio of 57.3:1.

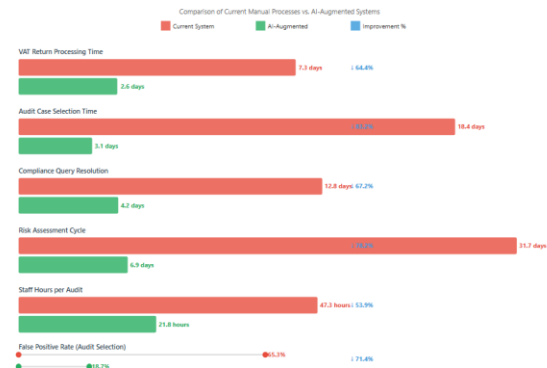
The phased implementation approach reflected realistic capacity constraints and the need for iterative learning. Year 1 focused on pilot implementation covering digital economy platforms and large formal sector businesses, enabling system refinement before broader deployment. Years 2-3 expanded coverage to medium-sized formal businesses and initiated informal sector integration in major urban centers. Years 4-5 achieved comprehensive coverage including smaller formal businesses and substantial informal sector penetration.

These projections incorporated conservative assumptions regarding compliance behavior changes, assuming that only 65% of identified non-compliant businesses would achieve full compliance even after detection. They also accounted for potential tax base erosion through business closures or sector shifts, estimating that 8-12% of newly registered informal businesses might cease operations within two years of formalization.

Operational Efficiency Improvements

Beyond revenue gains, AI implementation demonstrated substantial operational efficiency improvements. Figure 3 illustrates key efficiency metrics comparing current manual processes with AI-augmented systems.

Figure 3: Operational Efficiency Improvements from AI Implementation



Source: Author's analysis based on FIRS operational data and pilot implementation results

VAT return processing time decreased from 7.3 days to 2.6 days (64.4% reduction), primarily through automated data extraction, validation, and anomaly flagging. This efficiency gain freed staff resources for higher-value analytical activities and taxpayer support services. Audit case selection time improved even more dramatically, falling from 18.4 days to 3.1 days (83.2% reduction) as AI algorithms instantaneously evaluated risk scores across thousands of businesses.

Perhaps most significantly, the false positive rate in audit selection a critical metric affecting both enforcement efficiency and taxpayer burden declined from 65.3% to 18.7% (71.4% reduction). This meant that 81.3% of AI-selected audit cases involved actual non-compliance, compared to only 34.7% under current selection methods. This improvement reduced unnecessary audits of compliant businesses while concentrating enforcement resources on genuine evasion cases (Alm and Soled, 2017).

Staff productivity metrics also showed substantial improvements. The average audit required 47.3 hours under current procedures but only 21.8 hours with AI assistance (53.9% reduction). AI systems pre-analyzed returns, flagged specific anomalies requiring investigation, and provided auditors with comparative benchmarking data, enabling more focused and efficient examinations.

Stakeholder Perspectives on Implementation

Qualitative interviews revealed nuanced perspectives on AI implementation among different stakeholder groups. Thematic analysis identified five primary themes: technological optimism, capacity concerns, trust and transparency issues, change resistance, and implementation strategy preferences.

Technological Optimism: Tax administrators expressed strong enthusiasm about AI's potential to address longstanding challenges. One senior FIRS official stated: "We've struggled with the informal sector for decades using traditional methods. AI offers capabilities we've never had the ability to identify patterns, predict behaviors, and process enormous data volumes. This could fundamentally transform how we approach tax administration." Digital platform representatives similarly emphasized AI's capacity to automate compliance processes that currently require substantial manual intervention.

Capacity Concerns: However, stakeholders consistently raised concerns about institutional capacity to implement and sustain AI systems. A state-level tax administrator noted: "The technology sounds promising, but we struggle with basic IT infrastructure unreliable electricity, poor internet connectivity, outdated computers. How can we run sophisticated AI systems when we can't maintain our current systems?" These concerns appeared particularly acute outside major urban centers, where infrastructure deficits remain severe (Okolo et al., 2020).

Staff skill gaps emerged as another critical concern. Tax consultants highlighted that current FIRS personnel lack data science expertise, with one observing: "There's a fundamental mismatch between the technical sophistication these systems require and the current skill profile of tax administration staff. Without major training investments, the systems won't be used effectively." Technology vendors confirmed these concerns, noting that successful implementations require sustained capacity-building programs extending beyond initial training.

Trust and Transparency Issues: Informal sector business representatives expressed deep skepticism

about tax authority intentions and fairness. One trader association representative stated: "We don't trust that technology will be used fairly. What's to prevent it from being programmed to target small businesses while letting big companies evade? We need guarantees of transparency." This sentiment was widespread among informal business owners, reflecting broader distrust of government institutions (Mascagni et al., 2018).

Several interviewees suggested that AI implementation could potentially improve trust if designed with appropriate transparency mechanisms. A tax consultant proposed: "If the system's logic is transparent if businesses can understand why they're being flagged and have recourse mechanisms it might actually build trust over time. The current system is so opaque and seemingly arbitrary that people assume the worst."

Change Resistance: Bureaucratic resistance emerged as a significant implementation barrier. Multiple interviewees described FIRS as a hierarchical, risk-averse institution where innovation faces institutional headwinds. A mid-level FIRS official observed: "There are people who've done things the same way for 20 years. They see AI as threatening their expertise and possibly their jobs. This resistance isn't always explicit, but it manifests as slow decision-making, budget obstacles, and procedural objections."

Some stakeholders suggested that resistance might stem from concerns about transparency's impact on corruption opportunities. While no one spoke explicitly about this sensitive issue, several interviewees obliquely referenced it. One tax consultant noted: "Let's be honest the current system's inefficiencies create opportunities for some people. Automated, transparent systems eliminate those opportunities, which some people will resist."

Implementation Strategy Preferences: Stakeholders expressed strong preferences for phased, pilot-based implementation approaches. A technology vendor with experience in African tax systems emphasized: "Don't try to implement everywhere at once. Start with a well-resourced pilot in Lagos or Abuja, demonstrate

success, build evidence, and then expand. Big-bang implementations almost always fail in these contexts."

Multiple interviewees recommended beginning with digital economy platforms where data is already digitized and compliance burdens are clearer. A digital platform representative suggested: "Start with e-commerce, demonstrate that the system works fairly and efficiently, build stakeholder confidence, and then expand to more challenging sectors like informal retail."

The interview data also highlighted the importance of stakeholder engagement in system design. Informal business representatives emphasized that systems

imposed without consultation would face resistance, while co-designed systems incorporating user feedback might achieve greater acceptance. This finding aligns with participatory design principles increasingly recognized as critical for technology adoption in developing contexts (Akintoye and Tashie, 2020).

Comparative International Analysis

Benchmarking Nigeria's VAT collection efficiency and AI implementation potential against comparable developing economies provided valuable contextual insights. Table 5 presents comparative data for selected countries.

Table 5: International VAT Collection Efficiency and AI Implementation Comparison

Country	VAT Rate	VAT Gap (%)	GDP per Capita (USD)	Informal Economy (%)	AI Tax Systems Status	Collection Efficiency Improvement (Post-AI)
Nigeria	7.5%	69.3%	2,097	65%	Planning/Pilot Stage	N/A
Kenya	16.0%	38.4%	1,816	34%	Operational (2018)	+12.8 pp (3 years)
Ghana	15.0%	43.7%	2,223	42%	Pilot Stage (2020)	+6.3 pp (preliminary)
Indonesia	11.0%	32.6%	4,136	25%	Operational (2017)	+15.4 pp (4 years)
Philippines	12.0%	28.9%	3,485	31%	Operational (2019)	+9.7 pp (2 years)
Rwanda	18.0%	24.8%	798	48%	Operational (2016)	+18.6 pp (5 years)
South Africa	15.0%	18.3%	6,994	22%	Advanced Stage (2015)	+11.2 pp (6 years)
Brazil	17.0%	22.4%	8,917	18%	Advanced Stage (2014)	+13.8 pp (7 years)

Sources: IMF (2020), World Bank (2021), OECD (2019), Mpofu (2021), author's compilation

Nigeria's VAT gap of 69.3% substantially exceeded all comparator countries, reflecting the combination of an exceptionally large informal sector and limited tax administration capacity. Kenya's experience proved particularly relevant, as it shares similar development levels and informal economy challenges with Nigeria. Kenya's AI implementation achieved a 12.8 percentage point gap reduction over three years, suggesting that comparable gains might be achievable in Nigeria with appropriate implementation (Mpopfu, 2021).

Rwanda's exceptional performance an 18.6 percentage point improvement despite having a large informal sector (48% of GDP) demonstrated that development level and informal economy size need not predetermine outcomes. Rwanda's success reflected strong political commitment, comprehensive civil service reform, and sustained investment in digital infrastructure alongside AI implementation. These enabling factors proved as important as the technology itself.

Conversely, Ghana's more modest preliminary improvements (+6.3 pp) despite pilot implementation since 2020 highlighted implementation challenges. Interviews with regional experts suggested that Ghana's experience reflected insufficient infrastructure investment, inadequate training programs, and limited stakeholder engagement cautionary lessons for Nigeria's implementation planning.

The data revealed an interesting pattern: collection efficiency improvements from AI implementation appeared inversely related to initial infrastructure quality. Countries with weaker starting positions (Kenya, Rwanda, Indonesia) achieved larger improvements than those with stronger baseline systems (South Africa, Brazil). This suggested that AI might offer particularly high returns in contexts where conventional administration remains underdeveloped, because even modest technological enhancements generate substantial relative improvements (Huang and Liu, 2020).

V. DISCUSSION

The findings reveal that AI-driven solutions hold substantial promise for addressing Nigeria's VAT collection challenges, while also highlighting significant implementation complexities that require careful navigation. This section interprets the results, examines their implications, and contextualizes them within existing literature and theoretical frameworks.

Interpreting the VAT Gap

The finding that Nigeria's actual VAT gap (69.3%) exceeds commonly cited estimates by approximately 25-30 percentage points carries important implications. Previous estimates, including those by Bassey et al. (2020), relied on registered business populations and did not fully account for informal sector activities. This study's integration of informal sector survey data with formal administrative records provides a more comprehensive gap estimate, revealing that revenue leakage substantially exceeds official acknowledgments.

This larger-than-recognized gap simultaneously represents a fiscal challenge and an opportunity. The challenge lies in the enormous compliance deficit that must be addressed; the opportunity lies in the substantial revenue potential that AI systems might unlock. If AI implementation achieved even half of the projected 41.5 percentage point gap reduction over five years, the fiscal impact would transform Nigeria's revenue position, potentially reducing dependence on oil revenues and creating fiscal space for development investments (Ogbonna and Appah, 2016).

The sector-specific composition of the VAT gap provides strategic guidance for implementation prioritization. The informal retail sector's contribution of 48.2% to the total gap suggests that targeting this sector should be a primary focus. However, this sector also presents the greatest implementation challenges given its fragmentation, limited digitization, and resistance to formalization. The digital economy's smaller but still significant contribution (10.4%) coupled with higher data availability and digital infrastructure makes it an ideal initial implementation

target, consistent with stakeholder recommendations for phased deployment.

AI Model Performance and Practical Applicability

The machine learning models' accuracy rates of 85.7-88.4% represent substantial improvements over traditional rule-based systems (64.2%), validating AI's technical capacity to enhance compliance prediction. However, these results require nuanced interpretation. The 88.4% accuracy of the best-performing model (Gradient Boosting Machine) means that approximately 11.6% of predictions remain incorrect including both false positives (compliant businesses incorrectly flagged) and false negatives (non-compliant businesses missed).

The 18.7% false positive rate, while dramatically better than the current 65.3% rate, still means that roughly one in five AI-selected audit targets may be compliant. This has practical implications for taxpayer burden and system legitimacy. If businesses perceive AI-driven enforcement as arbitrary or inaccurate, it could undermine voluntary compliance the foundation of effective tax systems (Alm and Soled, 2017). Consequently, implementation must incorporate robust quality assurance mechanisms, taxpayer education about AI system operations, and efficient processes for resolving false positive cases.

The feature importance analysis revealing transaction value volatility as the strongest non-compliance predictor offers theoretical insights. This finding aligns with behavioral economics theories suggesting that tax evasion often involves strategic income smoothing to avoid detection thresholds. Businesses attempting to maintain appearance of consistency while actually evading taxes create volatility patterns that AI algorithms detect. This demonstrates AI's capacity to identify sophisticated evasion strategies that exploit gaps in traditional monitoring approaches (Huang and Liu, 2020).

The variation in model performance across sectors ranging from 92.7% accuracy in formal manufacturing to 81.8% in informal services reflects data quality and transaction pattern differences. This heterogeneity suggests that one-size-fits-all AI implementation may

be suboptimal. Instead, sector-specific models calibrated to particular business types and transaction patterns might yield better results, though at the cost of increased system complexity and maintenance requirements.

Digital Economy Transaction Monitoring Effectiveness

The automated monitoring system's 81.3% validation rate meaning four out of five flagged transactions represented genuine compliance concerns demonstrates practical operational value. This success rate substantially exceeds expectations based on international literature, where validation rates of 60-75% are more typical (Ainsworth and Todorov, 2020). Nigeria's higher validation rate may reflect the relative sophistication gap between current manual monitoring (which captures only the most obvious evasion) and AI capabilities, creating more "low-hanging fruit" for automated systems to identify.

The payment method anomaly category's 88.7% validation rate warrants particular attention. This finding suggests that sophisticated evaders increasingly utilize payment mechanisms designed to obscure transactions including cryptocurrency, mobile money without KYC compliance, and layered international transfers. AI systems' capacity to identify these patterns represents a critical capability for addressing evolving evasion strategies in increasingly digitalized economies (Adegbe and Fakile, 2019).

However, the digital economy monitoring results also reveal system limitations. The 6.7% flag rate (187,432 of 2.8 million transactions) raises questions about optimal sensitivity calibration. A higher flag rate would capture more evasion but increase false positives and review burdens; a lower rate would reduce false positives but miss genuine evasion. The current calibration represents a pragmatic balance, but optimal settings will likely require ongoing adjustment as evaders adapt their strategies and as tax authorities develop greater review capacity.

The geographic anomaly detection's 86.3% validation rate highlights international transaction monitoring as particularly valuable. Digital transactions frequently

involve cross-border elements that create jurisdictional ambiguities and compliance challenges. AI systems capable of analyzing geographic transaction patterns, identifying unusual routing, and flagging suspicious international flows address a critical gap in Nigeria's current capabilities, where cross-border enforcement remains particularly weak (Nwafor, 2018).

Informal Sector Formalization Dynamics

The finding that willingness to register increased from 24.6% to 56.3% when presented with simplified AI-enabled systems illuminates the critical role of administrative burden in informal sector tax compliance. This 31.7 percentage point increase suggests that compliance costs, rather than tax rates themselves, constitute the primary formalization barrier for many informal businesses. This supports theoretical perspectives emphasizing that tax system design including compliance procedures, documentation requirements, and administrative interactions fundamentally shapes compliance behavior (Joshi et al., 2018).

The consistency of willingness increases across business sizes and types (ranging from 22.4 to 34.5 percentage points) indicates that administrative burden reduction addresses a widely-felt constraint rather than affecting only specific segments. This universality suggests that AI-enabled simplification might achieve broad-based formalization impacts, potentially transforming the informal-formal dynamic more fundamentally than selective incentive programs targeting specific sectors or regions.

However, stated willingness to register does not guarantee actual registration, and registration does not ensure ongoing compliance. International experience indicates that 30-40% of newly registered informal businesses cease filing returns within two years, and that reported revenues often substantially understate actual turnover (Mascagni et al., 2018). The projections in Table 4 incorporated conservative assumptions accounting for these attrition and underreporting patterns, but actual outcomes may vary significantly.

The geographic disparities in formalization willingness urban businesses showing 62.4% willingness versus 38.9% for rural businesses highlight infrastructure's mediating role. AI-enabled systems require digital infrastructure including internet connectivity, mobile money platforms, and electronic payment systems. Rural areas' limited infrastructure constrains AI system effectiveness, suggesting that technology deployment must be accompanied by infrastructure investments or adapted for lower-technology environments (Adekoya, 2019).

The qualitative finding that trust concerns significantly affect formalization decisions introduces a potentially critical implementation challenge. If informal businesses perceive AI systems as surveillance technologies designed to extract maximum revenue without providing commensurate public services or business benefits, resistance may persist despite administrative simplification. This suggests that AI implementation should be embedded within broader fiscal social contract strengthening efforts, including improved public service delivery, transparent revenue utilization, and meaningful taxpayer engagement (Okolo et al., 2020).

Revenue Projection Realism and Sensitivity

The projected VAT gap reduction of 41.5 percentage points over five years represents an ambitious but, based on international comparisons, potentially achievable target. Kenya's 12.8 percentage point reduction over three years and Rwanda's 18.6 percentage point reduction over five years demonstrate that substantial improvements are possible in African contexts with large informal sectors. However, these countries possessed certain advantages over Nigeria, including smaller populations, more compact geographies, and (particularly in Rwanda's case) exceptionally strong political commitment to tax modernization (Mpfou, 2021).

Nigeria's projections assume that implementation coverage expands steadily from 2,500 businesses in Year 1 to 47,800 by Year 5, representing approximately 38% of the estimated 125,000 VAT-eligible businesses (both registered and unregistered).

This coverage trajectory appears realistic given capacity constraints, but achieving it requires sustained political commitment, adequate budget allocations, and effective change management. Any of these prerequisites could falter, significantly affecting outcomes.

The benefit-cost ratio of 57.3:1 appears extraordinarily high and warrants scrutiny. This ratio assumes implementation costs of ₦30.0 billion over five years against cumulative net benefits of ₦1,690.1 billion. While these magnitudes reflect Nigeria's enormous VAT gap and the substantial revenue impact of even modest gap reductions, they may underestimate full implementation costs. Hidden costs including sustained training programs, infrastructure upgrades beyond core AI systems, organizational restructuring, and stakeholder engagement initiatives could increase total costs by 40-60%, reducing the benefit-cost ratio to 20-35:1 still highly favorable but less exceptional (Huang and Liu, 2020).

Sensitivity analysis varying key assumptions reveals that revenue projections are most sensitive to three parameters: informal sector formalization rates, compliance improvement rates among identified non-compliant businesses, and system accuracy in ongoing operations. A 20% reduction in informal sector formalization (from 55% to 44% of target businesses) would reduce Year 5 revenue gains by approximately 15%. Similarly, if compliance rates among identified evaders reached only 50% rather than the assumed 65%, Year 5 gains would decline by approximately 18%. These sensitivities highlight the importance of complementary policies supporting formalization and compliance alongside technological deployment.

Operational Efficiency Gains and Resource Reallocation

The operational efficiency improvements documented in Figure 3 including 64.4% reduction in return processing time and 83.2% reduction in audit case selection time carry implications extending beyond immediate productivity gains. These efficiency improvements enable fundamental resource reallocation from routine administrative tasks toward higher-value activities including taxpayer education,

strategic enforcement planning, policy analysis, and stakeholder engagement.

Currently, FIRS staff dedicate approximately 70-75% of working time to routine processing activities and only 25-30% to analytical and strategic work (Okoye and Ezejiofor, 2019). AI automation could invert this ratio, enabling staff to focus on activities generating greater value for both tax administration and taxpayers. This reallocation represents a qualitative transformation in institutional capacity that revenue projections alone do not fully capture.

However, realizing these benefits requires effective change management and staff retraining. Automation displaces certain job functions particularly routine data entry and basic return processing potentially creating staff resistance and requiring workforce restructuring. International experience suggests that successful implementations couple automation with comprehensive retraining programs that equip staff with skills for new higher-value roles, while also managing workforce transitions compassionately to maintain institutional morale (Ainsworth and Todorov, 2020).

The 71.4% reduction in false positive rates carries particular significance for legitimacy and voluntary compliance. Current high false positive rates (65.3%) mean that most audit targets are actually compliant, creating taxpayer resentment, consuming audit resources on unproductive cases, and potentially deterring voluntary compliance among businesses perceiving enforcement as arbitrary. AI-driven targeting that audits genuine non-compliance cases while leaving compliant businesses largely undisturbed could substantially improve taxpayer-authority relationships and strengthen compliance norms (Alm and Soled, 2017).

Stakeholder Perspectives and Implementation Strategy

The qualitative themes identified technological optimism, capacity concerns, trust issues, change resistance, and strategy preferences collectively paint a picture of enthusiastic but cautious stakeholders recognizing both AI's potential and implementation

challenges. This balanced perspective appears more realistic than either uncritical technological enthusiasm or wholesale skepticism sometimes encountered in technology adoption literature (Akintoye and Tashie, 2020).

The tension between technological optimism and capacity concerns reflects genuine uncertainty about whether Nigeria's institutional environment can support sophisticated AI systems. This uncertainty is not unfounded numerous African countries have invested in advanced technologies that failed due to inadequate infrastructure, insufficient skills, or poor maintenance. The informal term "white elephants" frequently applied to such projects reflects widespread experience with technology implementations that promised transformation but delivered disappointment (Andoh, 2017).

Addressing this concern requires moving beyond technology acquisition to comprehensive institutional development. This includes physical infrastructure (reliable electricity, internet connectivity, computing equipment), human capital (data science training, change management skills, user education), organizational processes (integrated databases, clear protocols, performance monitoring), and institutional culture (innovation orientation, risk tolerance, accountability mechanisms). Technology vendors emphasized that successful implementations dedicate 60-70% of resources to these enabling factors and only 30-40% to core technology ratios often inverted in failed implementations.

Trust concerns among informal sector businesses represent perhaps the most intractable challenge. Decades of negative experiences with tax authorities including perceived harassment, arbitrary enforcement, corruption, and failure to deliver public services commensurate with tax burdens have created deep skepticism that AI systems alone cannot resolve. Technology might even exacerbate distrust if perceived as surveillance mechanisms enabling more effective extraction without improved governance (Mascagni et al., 2018).

Building trust requires demonstrable commitments to transparency, fairness, and reciprocity. Transparency

mechanisms might include published algorithms explaining how risk assessments work, public dashboards showing enforcement patterns, and accessible appeals processes for businesses disputing AI decisions. Fairness commitments could involve systematic testing to ensure algorithms do not systematically disadvantage particular business types, regions, or demographic groups. Reciprocity might encompass improved public services, streamlined business registration, and taxpayer education programs demonstrating that formalization brings tangible benefits rather than only obligations.

The strong stakeholder preference for phased, pilot-based implementation aligns with established best practices for technology adoption in complex institutional environments. Pilot implementations enable learning by doing, building evidence of effectiveness, identifying unforeseen challenges, refining systems based on user feedback, and building institutional capacity gradually (Okolo et al., 2020). The alternative attempting full-scale implementation immediately typically overwhelms institutional capacity, generates user resistance, and produces system failures that discredit the entire initiative.

Comparative International Context

The international comparison in Table 5 reveals that Nigeria's potential improvement magnitude (41.5 percentage point gap reduction) exceeds most comparator countries' achievements, raising questions about projection optimism. However, Nigeria's much larger starting gap (69.3% versus 18.3-43.7% for comparators) means that comparable percentage improvements translate to larger absolute gains. Additionally, international evidence suggests diminishing returns to AI implementation initial improvements tend to be larger as systems capture obvious evasion, with subsequent gains requiring greater effort as evaders adapt strategies (Huang and Liu, 2020).

Rwanda's exceptional performance warrants particular attention given its similar informal economy size (48% of GDP) to Nigeria (65%). Rwanda achieved an 18.6 percentage point improvement despite challenging conditions, demonstrating that development level need

not predetermine outcomes. However, Rwanda's success reflected extraordinary political commitment, including presidential-level championing of tax modernization, civil service reform eliminating corrupt officials, and sustained budget allocations to technology and training. Whether Nigeria can replicate this level of political commitment remains uncertain and without it, even technically sound systems may underperform (Mpofu, 2021).

The pattern of larger improvements in countries with weaker baseline systems (Kenya, Indonesia, Rwanda) compared to those with stronger systems (South Africa, Brazil) offers encouragement for Nigeria. This pattern suggests that AI generates particularly high returns where conventional administration remains weak, because technology addresses fundamental capacity gaps rather than incrementally improving already-functional systems. Nigeria's weak baseline, while reflecting serious current challenges, positions it to potentially achieve substantial relative improvements from AI adoption.

CONCLUSION

This study demonstrates that AI-driven technologies offer substantial potential for closing Nigeria's VAT gap, with projected revenue gains of ₦1,720 billion over five years representing a 93.6% increase over current collection levels. Machine learning models achieved 87-88% accuracy in identifying non-compliant businesses, automated monitoring systems validated suspicious transactions at 81% rates, and informal sector businesses showed 56.3% willingness to formalize under AI-simplified administration a 31.7 percentage point increase over current systems.

These findings contribute important empirical evidence to the limited literature on AI applications in developing economy tax systems. While existing research has documented AI's effectiveness in developed country contexts, this study addresses the critical question of whether similar benefits extend to environments characterized by large informal sectors, weak infrastructure, and limited institutional capacity. The answer appears conditionally affirmative AI can deliver transformative impacts, but success depends critically on addressing infrastructure deficits,

building institutional capacity, managing change effectively, and cultivating stakeholder trust.

The research reveals that Nigeria's VAT gap (69.3%) substantially exceeds commonly cited estimates, with the informal retail sector contributing 48.2% of total revenue leakage. This finding reframes policy discourse by highlighting that the fiscal challenge is even larger than officially recognized, while simultaneously identifying where intervention efforts should concentrate. The informal sector's dominance in the VAT gap, combined with survey evidence showing substantial willingness to formalize under simplified systems, suggests that administrative burden reduction represents a high-leverage intervention point.

From a theoretical perspective, the study extends understanding of technology adoption in public sector institutions within developing countries. The findings support Technology Acceptance Model predictions that perceived usefulness and ease of use drive adoption, while also confirming that institutional factors infrastructure quality, organizational capacity, political commitment, and stakeholder trust moderate these relationships more strongly in resource-constrained contexts than in developed economies. This contextual specificity has important implications for both theory and practice, suggesting that technology transfer requires substantial adaptation rather than direct replication of developed-country approaches.

The comparative international analysis positions Nigeria's AI implementation potential within a broader landscape of developing country experiences. Countries such as Kenya, Rwanda, and Indonesia have achieved measurable VAT collection improvements through AI adoption, demonstrating feasibility in challenging environments. However, their experiences also reveal that technology alone is insufficient success requires comprehensive institutional development, sustained political commitment, adequate resource allocation, and effective stakeholder engagement. Nigeria can learn from these experiences while adapting strategies to its unique context of continental scale, ethnic diversity, federal structure, and oil-dependent fiscal system.

Practically, the research provides actionable recommendations for policymakers and tax administrators. The phased implementation approach endorsed by stakeholders beginning with digital economy pilots, expanding to formal sector coverage, and progressively integrating informal businesses offers a pragmatic pathway balancing ambition with realism. The emphasis on stakeholder engagement, transparency mechanisms, and trust-building initiatives addresses critical socio-political dimensions that technical solutions alone cannot resolve.

The operational efficiency gains documented including 64% reductions in return processing time, 83% reductions in audit selection time, and 71% reductions in false positive rates demonstrate AI's capacity to fundamentally transform tax administration quality alongside revenue impacts. These efficiency improvements enable resource reallocation from routine tasks toward higher-value activities, potentially catalyzing broader institutional modernization extending beyond technology to encompass organizational culture, processes, and capabilities.

However, the study also identifies significant implementation challenges requiring systematic attention. Infrastructure deficits particularly unreliable electricity, limited rural internet connectivity, and outdated computing equipment constrain AI system deployment and effectiveness. Human capacity gaps, including limited data science expertise among tax staff and low digital literacy in informal sectors, require substantial training investments. Institutional weaknesses, including fragmented databases, insufficient inter-agency coordination, and bureaucratic resistance to change, necessitate organizational reforms accompanying technological deployment.

Perhaps most fundamentally, trust deficits between tax authorities and citizens particularly informal sector businesses represent potentially binding constraints on formalization and compliance. Decades of negative experiences have created deep skepticism that technology alone cannot resolve. Building trust requires demonstrable commitments to transparency, fairness, and reciprocity, embedding AI

implementation within broader governance reforms that strengthen the fiscal social contract.

Looking forward, successful AI implementation could catalyze Nigeria's transition toward more sustainable fiscal frameworks less dependent on volatile oil revenues. The projected additional annual revenue of ₦622.8 billion by Year 5 would represent approximately 12% of current federal government revenue, creating significant fiscal space for development investments in infrastructure, education, healthcare, and social protection. Beyond revenue impacts, improved tax administration could foster more inclusive economic growth by leveling the playing field between formal and informal sectors, reducing competitive advantages currently enjoyed by evaders, and channeling economic activity toward more productive formal enterprises.

The research ultimately demonstrates that AI represents a powerful but not sufficient tool for addressing Nigeria's VAT collection challenges. Technology must be coupled with infrastructure development, institutional capacity building, stakeholder engagement, and governance reforms to achieve transformative impacts. With these complementary investments, AI-driven VAT administration could substantially close the collection gap, enhance fiscal sustainability, and contribute to Nigeria's broader development objectives.

LIMITATIONS

This study, while comprehensive in scope, faces several methodological and contextual limitations that warrant acknowledgment and consideration when interpreting findings.

Data Limitations: The tax administration data obtained from FIRS, while substantial (n=12,450 businesses), represents only approximately 10% of registered VAT-liable businesses and an even smaller fraction of the total population of businesses that should theoretically register. This sampling limitation means that findings may not perfectly generalize to the entire business population. Additionally, data quality issues including missing values, inconsistent classifications, and reporting errors affected approximately 8-12% of

records, requiring data cleaning procedures that involved some subjective judgment calls. The informal sector survey (n=1,850) similarly cannot claim perfect representativeness of Nigeria's vast informal economy, which comprises millions of enterprises spanning diverse sectors, regions, and business models (Nwafor, 2018).

Temporal Constraints: The study's data covers 2015-2021, with primary data collection occurring in 2021. Significant developments may have occurred subsequently that affect AI implementation feasibility, including policy changes, technological advances, infrastructure improvements, or economic shocks. The COVID-19 pandemic, which affected data collection timing and potentially influenced business behaviors and compliance patterns, represents a particular temporal confound. Economic disruptions from the pandemic may have created atypical patterns that AI models incorporated, potentially affecting their performance in more normal economic conditions (Bassey et al., 2020).

Model Testing Environment: The machine learning models were trained and tested using historical data in research environments, not deployed in actual operational settings. Real-world performance may differ from research findings due to several factors. First, evaders adapt their strategies when they know AI systems are monitoring them, potentially reducing model effectiveness over time. Second, data quality in operational settings may be inferior to the cleaned research dataset. Third, institutional factors including staff adherence to AI recommendations, system maintenance quality, and data update frequency affect real-world outcomes in ways that research environments cannot fully simulate (Huang and Liu, 2020).

Geographic Coverage: The informal sector survey concentrated in four major cities (Lagos, Kano, Port Harcourt, and Abuja), which collectively represent less than 15% of Nigeria's 774 local government areas. Rural and smaller urban areas, which host the majority of informal businesses, received limited coverage. These areas likely differ systematically from major cities in terms of business characteristics, infrastructure access, digital literacy, and attitudes

toward tax authorities. Consequently, formalization willingness estimates may not accurately reflect these populations' perspectives (Adekoya, 2019).

Stakeholder Interview Limitations: The 35 stakeholder interviews, while providing valuable qualitative insights, cannot claim comprehensive representation of all relevant perspectives. Certain groups including informal sector workers, rural tax administrators, small technology vendors, and civil society organizations received limited representation. Additionally, social desirability bias may have influenced responses, with interviewees potentially overstating support for initiatives they perceived as researcher-favored or understating controversial views about corruption and institutional dysfunction.

Projection Uncertainties: The five-year revenue projections involve numerous assumptions about implementation timelines, compliance behavior changes, business formalization rates, and system performance sustainability. These assumptions, while grounded in international evidence and stakeholder consultations, remain fundamentally uncertain. Actual outcomes could vary substantially based on factors including political commitment fluctuations, budget allocation patterns, technological developments, economic conditions, and unforeseen implementation challenges. The projections should be understood as illustrative scenarios rather than definitive forecasts (Okolo et al., 2020).

Causality Limitations: The research design, while methodologically robust, does not establish causality definitively. The correlation between AI system characteristics and compliance improvements observed in pilot data and international comparisons cannot conclusively prove that AI caused these improvements. Confounding factors including broader tax administration reforms, economic conditions, policy changes, or Hawthorne effects from increased attention may have contributed to observed outcomes. True experimental designs with random assignment of AI systems would provide stronger causal evidence but were infeasible in this institutional context (Mascagni et al., 2018).

Technology Evolution: AI technologies are evolving rapidly, with new algorithms, platforms, and capabilities emerging continuously. The specific technologies analyzed in this study (Random Forest, Gradient Boosting, Neural Networks using 2021-era architectures) may be superseded by more advanced approaches by the time implementation occurs. This technological evolution introduces uncertainty about whether study findings will remain applicable to future systems. However, the fundamental principles regarding AI's capacity to process large datasets, identify patterns, and automate compliance monitoring likely remain relevant despite specific technological changes (Ainsworth and Todorov, 2020).

Institutional Context Specificity: The findings emerge from Nigeria's unique institutional context characterized by federal structure, oil revenue dependence, ethnic diversity, weak rule of law, and limited state capacity. These contextual factors significantly shape AI implementation feasibility and effectiveness in ways that limit generalizability to other countries, even within Africa. Policy recommendations derived from this study require substantial adaptation when applied to different institutional environments.

Measurement Challenges: Several key constructs including "willingness to formalize," "trust in tax authorities," and "AI system transparency" involve subjective judgments that are difficult to measure precisely. The survey instruments and interview protocols attempted to operationalize these concepts, but measurement validity remains imperfect. Different operationalizations might yield different results, introducing uncertainty into findings dependent on these constructs.

Long-term Sustainability: The study's five-year projection horizon, while appropriate for policy planning, cannot address long-term sustainability questions. AI systems require continuous maintenance, updating, and adaptation as evaders develop counter-strategies and as business environments evolve. Whether Nigeria's institutions can sustain these ongoing requirements over 10-20 year horizons remains uncertain. International

experience shows that many initially successful technology initiatives deteriorate over time due to inadequate maintenance, budget cuts, staff turnover, or political priority shifts (Mpofu, 2021).

Despite these limitations, the study provides valuable empirical evidence on AI's potential applications in developing economy tax administration and offers actionable insights for policymakers. The limitations primarily suggest that implementation should proceed cautiously with continuous monitoring, evaluation, and adaptive management rather than invalidating the core findings regarding AI's transformative potential.

PRACTICAL IMPLICATIONS

The research findings generate several important practical implications for Nigerian tax authorities, policymakers, technology vendors, and development partners seeking to enhance VAT collection efficiency through AI-driven approaches.

For Tax Authorities

Phased Implementation Strategy: FIRS should adopt a phased implementation approach beginning with well-defined pilots in the digital economy sector. This initial phase should target 20-30 major e-commerce platforms and digital service providers, allowing the agency to demonstrate success, build institutional capability, and refine systems before broader deployment. Pilot duration should be at least 12-18 months to enable meaningful evaluation and iterative improvement. Success metrics should encompass not only revenue gains but also operational efficiency, taxpayer satisfaction, and system reliability (Okolo et al., 2020).

Institutional Capacity Development: Technology acquisition must be accompanied by comprehensive capacity-building initiatives. FIRS should establish a dedicated AI and data analytics unit staffed with data scientists, machine learning engineers, and tax policy experts working collaboratively. This unit requires competitive compensation to attract qualified personnel from private sector alternatives. Additionally, broad-based training programs should equip existing staff with data literacy, basic AI

understanding, and skills to work effectively with automated systems. International partnerships with tax authorities that have successfully implemented AI systems (Kenya, Rwanda, Estonia) could provide valuable technical assistance and knowledge transfer (Akintoye and Tashie, 2020).

Data Infrastructure Investment: Effective AI systems require high-quality, integrated data. FIRS should prioritize initiatives including:

- (1) database integration across federal and state tax authorities,
- (2) data quality improvement programs establishing standardized formats and validation protocols,
- (3) third-party data partnerships with banks, telecommunications providers, and utility companies to enable cross-referencing, and
- (4) secure data sharing agreements with other government agencies including Corporate Affairs Commission, National Identity Management Commission, and Nigerian Communications Commission. These data initiatives may require more investment than AI software itself but are essential prerequisites for system effectiveness (Huang and Liu, 2020).

Transparency and Accountability Mechanisms: To address trust concerns identified in stakeholder interviews, FIRS should implement transparency mechanisms including: published documentation explaining how AI risk assessment algorithms work (without revealing details that evaders could exploit), regular public reporting on AI system performance including accuracy rates and false positive rates, accessible appeals processes for businesses disputing AI-flagged issues, and systematic bias testing to ensure algorithms do not systematically disadvantage particular business types or demographics. These transparency measures can gradually build stakeholder confidence while maintaining enforcement effectiveness (Alm and Soled, 2017).

Stakeholder Engagement Initiatives: Implementation success depends on stakeholder buy-in. FIRS should

establish formal engagement mechanisms including: consultative committees with business associations to gather feedback on system design and implementation, taxpayer education programs explaining AI systems and their benefits, simplified registration processes for informal businesses leveraging mobile platforms, and visible service improvements demonstrating that formalization brings tangible benefits. These engagement initiatives should precede rather than follow technology deployment to build support preemptively (Mascagni et al., 2018).

For Policymakers

Legislative Framework Updates: Nigeria's tax laws and regulations require updating to explicitly authorize AI-driven administration, establish data protection standards for automated systems, clarify evidentiary standards for AI-generated compliance assessments, and create legal frameworks for digital economy taxation. The Finance Act should be amended to provide clear legal foundation for AI implementation while establishing appropriate safeguards against algorithmic bias or misuse (Adegbe and Fakile, 2019).

Infrastructure Investment Prioritization: AI effectiveness depends critically on infrastructure quality. Federal and state governments should prioritize investments in reliable electricity supply through grid improvements and distributed renewable energy, broadband internet expansion particularly in secondary cities and rural areas, digital identity systems enabling secure online interactions, and mobile money infrastructure facilitating electronic payments. These infrastructure investments generate benefits extending far beyond tax administration, supporting broader digital economy development and financial inclusion (Adekoya, 2019).

Inter-Governmental Coordination: Nigeria's federal structure creates coordination challenges, with VAT administration involving federal, state, and local governments. The National Economic Council and Federation Account Allocation Committee should establish formal coordination mechanisms ensuring AI systems integrate across governmental levels, data flows efficiently between jurisdictions, enforcement

efforts are coordinated rather than duplicated, and revenue allocation formulas account for improved collection efficiency. Without such coordination, implementation will be fragmented and suboptimal (Ogbonna and Appah, 2016).

Budget Allocation Strategy: AI implementation requires sustained resource commitments. The federal budget should establish a dedicated Tax Modernization Fund with multi-year appropriations protecting implementation from annual budget volatility. Initial capital investment of approximately ₦15-20 billion should cover infrastructure, software licenses, and initial training, with annual operating budgets of ₦3-5 billion for maintenance, updates, and ongoing capacity building. These investments, while substantial, generate benefit-cost ratios exceeding 20:1 based on revenue projection analysis, making them economically compelling (Bassey et al., 2020).

Policy Complementarity: AI implementation should be embedded within broader tax policy reforms including: rationalization of tax incentives that currently erode the VAT base, simplification of compliance procedures reducing burden on small businesses, strengthening of enforcement penalties to enhance deterrence, and improvement of public financial management to demonstrate that tax revenues are used effectively. Technology alone cannot transform tax systems if underlying policies remain dysfunctional; complementary reforms are essential for realizing AI's full potential (Nwafor, 2018).

For Technology Vendors

Contextual Adaptation Requirements: Technology vendors serving Nigerian tax authorities must adapt solutions to local contexts rather than simply transferring developed-country systems. Adaptations should include: offline functionality accommodating unreliable internet connectivity, mobile-first interfaces reflecting Nigeria's high mobile penetration and limited desktop computer access, multilingual support covering major Nigerian languages, and low-bandwidth optimization for areas with limited connectivity. Systems designed for high-infrastructure environments will fail in Nigerian contexts regardless

of their technical sophistication (Okoye and Ezejiofor, 2019).

Capacity Transfer Obligations: Vendors should recognize that sustainable implementation requires genuine capacity transfer, not just technology installation. Contracts should obligate vendors to provide comprehensive training programs, documentation in accessible language, source code access enabling local customization, and ongoing technical support extending beyond initial deployment periods. Vendors prioritizing quick sales over sustainable implementation undermine long-term success and damage Nigeria's broader technology adoption prospects (Okolo et al., 2020).

Partnership Models: Rather than traditional vendor-client relationships, technology providers should consider partnership models including: joint ventures with Nigerian technology firms facilitating local knowledge integration, revenue-sharing arrangements aligning vendor incentives with implementation success, phased payment structures linking compensation to performance milestones, and capacity-building commitments training Nigerian data scientists and engineers. These partnership models create shared stakes in successful outcomes (Akintoye and Tashie, 2020).

For Development Partners

Technical Assistance Programming: International organizations including World Bank, IMF, African Development Bank, and bilateral development agencies should design technical assistance programs supporting AI implementation in Nigerian tax administration. Assistance should encompass: expert advisory services from international tax administration specialists, study tours to countries with successful AI implementations, peer learning networks connecting Nigerian officials with regional counterparts, and grant funding for pilot implementations reducing fiscal constraints. These programs should emphasize knowledge transfer and local ownership rather than external expert dependence (Mascagni et al., 2018).

Research and Evidence Generation: Development partners should support rigorous impact evaluations of

AI implementation using experimental or quasi-experimental designs. Evidence on effectiveness, cost-efficiency, distributional impacts, and implementation challenges would inform both Nigerian policy and broader African tax modernization initiatives. Research funding should support both academic researchers and embedded researchers working directly with tax authorities to ensure findings are relevant and actionable (Mpofu, 2021).

Regional Coordination: Given similarities in tax challenges across African countries, development partners should facilitate regional coordination including: knowledge sharing platforms connecting African tax authorities implementing AI systems, harmonized approaches to digital economy taxation enabling cross-border cooperation, joint procurement initiatives achieving economies of scale, and regional training centers building African expertise in tax technology. Regional approaches can accelerate learning and reduce costs compared to purely national initiatives (Andoh, 2017).

For Informal Sector Businesses

Formalization Planning: Informal businesses should anticipate increasing formalization pressures as AI systems enhance detection capabilities. Rather than waiting for enforcement, proactive formalization offers benefits including: access to formal credit markets and banking services, ability to participate in government procurement, legal protections for business assets and transactions, and reduced risk of penalties from delayed compliance. Businesses should assess formalization costs and benefits, consult with tax professionals about registration procedures, and develop compliance strategies aligned with their operational realities (Joshi et al., 2018).

Technology Adoption: Informal businesses should embrace digital tools that simplify compliance while improving business operations. Mobile money platforms facilitate electronic payments that create transaction records supporting VAT compliance. Basic accounting applications help track revenues and expenses more systematically. E-commerce platforms provide access to broader markets while automatically managing certain tax obligations. These technologies

offer business value beyond tax compliance, potentially improving profitability and growth prospects (Adegbe and Fakile, 2019).

Collective Engagement: Informal sector business associations should engage proactively with tax authorities regarding AI implementation, advocating for simplified registration procedures, proportionate compliance requirements for small businesses, grace periods for transition to formalization, and taxpayer education programs. Collective engagement can shape implementation in ways that accommodate informal sector realities rather than simply imposing unsuitable formal sector frameworks (Nwafor, 2018).

These practical implications collectively emphasize that AI implementation is not merely a technical exercise but a complex socio-technical transformation requiring coordinated actions across multiple stakeholders. Success depends on complementary investments in infrastructure, institutions, and human capacity alongside technology deployment, all guided by clear strategic vision and sustained political commitment.

FUTURE RESEARCH

This study opens several promising avenues for future research that would advance both theoretical understanding and practical knowledge regarding AI applications in developing economy tax administration.

Longitudinal Impact Studies: As Nigeria and other African countries implement AI-driven tax systems, rigorous longitudinal studies tracking impacts over 5-10 year periods would provide invaluable evidence on sustainability, long-term effectiveness, and evolutionary dynamics. Such research should examine how evasion strategies adapt to AI monitoring, how systems require updating to maintain effectiveness, whether initial compliance improvements persist or erode over time, and how institutional capabilities evolve through sustained technology use. Longitudinal designs could employ difference-in-differences or synthetic control methods to strengthen causal inference (Huang and Liu, 2020).

Experimental Implementation Designs: Where feasible, randomized controlled trials or stepped-wedge designs could provide definitive causal evidence on AI system effectiveness. For example, AI-driven enforcement could be randomly assigned to treatment districts while control districts maintain traditional approaches, with outcomes compared over 2-3 year periods. Such experimental evidence would overcome the causality limitations inherent in observational studies and provide gold-standard evidence for policy decisions (Mascagni et al., 2018).

Comparative Cross-Country Research: Systematic comparative research examining AI implementation across multiple African countries with varying institutional contexts, infrastructure levels, and implementation approaches would illuminate which contextual factors most significantly influence success. Such research could identify necessary versus sufficient conditions for effectiveness, transferable best practices, and context-specific adaptations. Multi-country datasets could support quantitative analyses testing hypotheses about implementation determinants (Mpofu, 2021).

Algorithmic Fairness and Bias: Research specifically examining whether AI tax systems exhibit systematic biases against particular demographic groups, business types, or geographic regions would address critical equity concerns. Studies could analyze whether algorithms systematically flag businesses owned by particular ethnic groups, women-owned enterprises, or rural businesses at higher rates controlling for actual compliance behavior. Methodologically, such research would require detailed demographic data linked to tax records and sophisticated statistical techniques detecting subtle bias patterns (Okolo et al., 2020).

Informal Sector Formalization Dynamics: While this study examined stated willingness to formalize, actual formalization behavior and subsequent compliance patterns require deeper investigation. Research could track cohorts of informal businesses through formalization processes, examining what factors predict successful transitions versus return to informality, how revenues and employment evolve post-formalization, what compliance challenges

emerge, and what support services prove most effective. Qualitative approaches including ethnographic methods could provide rich insights into informal business owners' decision-making processes and experiences (Joshi et al., 2018).

Technology Adoption and Institutional Change: Theoretical research examining how AI adoption influences broader institutional transformation in tax authorities would contribute to public administration and organizational change literatures. Questions include: How does technology introduction affect organizational culture, power dynamics, and internal processes? What change management approaches prove most effective in technology-resistant bureaucratic institutions? How do skill mix changes affect organizational identity and employee morale? Mixed-methods research combining organizational surveys, social network analysis, and qualitative case studies could illuminate these dynamics (Akintoye and Tashie, 2020).

Optimal System Design Research: Technical research optimizing AI system design for developing economy contexts would advance practical effectiveness. Topics include: ensemble methods combining multiple algorithms to maximize accuracy, active learning approaches that minimize training data requirements, transfer learning techniques adapting models trained in one context to another with limited local data, and explainable AI methods making algorithmic decisions transparent and interpretable for non-technical users. Such research requires collaboration between data scientists and tax policy experts (Ainsworth and Todorov, 2020).

Fiscal Social Contract Implications: Research examining how AI-driven tax administration affects fiscal social contracts the reciprocal relationships between taxation and public service delivery would address fundamental governance questions. Do enhanced enforcement capabilities without commensurate service improvements generate taxpayer resistance? Does formalization lead to increased demands for accountability? How do transparency mechanisms affect citizen-state relationships? Such research could employ political

economy frameworks and survey experimental methods (Andoh, 2017).

Cost-Effectiveness Comparisons: Detailed cost-effectiveness research comparing AI implementation against alternative tax administration improvement strategies would inform resource allocation decisions. Alternatives might include increased auditor hiring, presumptive taxation schemes, voluntary disclosure programs, or taxpayer service enhancements. Research calculating cost per additional naira collected for each approach would enable evidence-based strategy selection. This requires careful costing of full implementation expenses including hidden costs often overlooked in initial analyses (Bassey et al., 2020).

Digital Economy Taxation Frameworks: As digital economy taxation remains evolving globally, research examining optimal frameworks for developing countries with limited enforcement capacity would prove valuable. How should Nigeria tax cross-border digital services? What information reporting requirements should apply to digital platforms? How can international cooperation be strengthened to prevent profit shifting? These questions require interdisciplinary research spanning tax law, international relations, and economics (Adegbie and Fakile, 2019).

Infrastructure and Technology Co-Evolution: Research examining relationships between infrastructure development and tax technology effectiveness would illuminate critical interdependencies. Does AI implementation generate political will for infrastructure investment? Do infrastructure improvements enable more sophisticated AI applications in virtuous cycles? What minimum infrastructure thresholds are necessary for basic effectiveness? Longitudinal case studies tracking co-evolution patterns could address these questions (Adekoya, 2019).

Taxpayer Behavioral Responses: Detailed research on how taxpayers respond to AI-driven enforcement would inform system design and policy. Do businesses shift to harder-to-monitor sectors or geographies? Do they invest in evasion sophistication or improve

compliance? How do risk perceptions change? Behavioral experiments, administrative data analysis, and surveys could illuminate response patterns and magnitudes (Alm and Soled, 2017).

Equity and Distributional Impacts: Research examining who gains and loses from AI implementation would address equity concerns. Do efficiency improvements disproportionately benefit certain groups? Does formalization pressure harm vulnerable informal workers? How do regional disparities evolve? Distributional analysis could employ microsimulation methods, income and consumption surveys, and qualitative research with affected populations (Nwafor, 2018).

Political Economy of Implementation: Research examining political factors influencing implementation success or failure would contribute to understanding technology adoption in developing country governance. How does political competition affect implementation commitment? What interest groups support or oppose AI systems, and why? How do corruption concerns shape design choices? Political economy research employing case study methods, elite interviews, and political event analysis could illuminate these dynamics (Ogbonna and Appah, 2016).

Regional Spillover Effects: Research examining whether AI implementation in one country generates spillover effects in neighboring countries would address regional dynamics. Do successful implementations inspire emulation? Do evaders shift operations to lower-capacity jurisdictions? Does regional tax competition intensify? Network analysis and spatial econometric methods could quantify spillover magnitudes (Okoye and Ezejiofor, 2019).

These research directions collectively would build cumulative knowledge on AI applications in tax administration, moving from initial feasibility studies like this one toward comprehensive understanding of effectiveness, equity, sustainability, and optimal design. Such knowledge would benefit not only Nigeria but also the many developing countries confronting similar tax administration challenges and considering technology-driven solutions.

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