

Application Of Artificial Intelligence In Enhancing The Accuracy And Efficiency Of National Population Censuses In Nigeria: A Conceptual Review

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Abstract— Accurate and efficient population census data are fundamental for national planning, resource allocation, and sustainable development. In Nigeria, past census exercises have been constrained by persistent challenges such as logistical difficulties, political interference, data inconsistencies, undercounting, and delays in data dissemination, which have undermined evidence-based policymaking. In response to these limitations, this study conceptually examines the application of Artificial Intelligence (AI) in enhancing the accuracy and efficiency of national population censuses in Nigeria. Adopting a conceptual review approach, the paper synthesizes existing literature, policy documents, and global best practices on AI-driven census modernization, with specific emphasis on data collection, processing, analysis, security, and operational management. The review highlights how AI technologies including machine learning, computer vision, satellite imagery, geospatial analytics, and predictive modeling can significantly improve population mapping, reduce enumeration errors, enhance real-time monitoring, and support timely demographic analysis. The study further identifies critical constraints to effective AI adoption in Nigeria's census processes, including infrastructural deficits, limited human capacity, ethical and legal concerns related to data privacy, funding challenges, and risks of algorithmic bias. Despite these challenges, the review finds that Nigeria demonstrates growing readiness for AI integration through ongoing digital reforms, expanding ICT infrastructure, and institutional strengthening within the National Population Commission. The paper concludes that, if strategically implemented within robust ethical, legal, and governance frameworks, AI presents a transformative opportunity to modernize Nigeria's census system into a digital-first, efficient, and reliable process. Such transformation would strengthen evidence-based decision-making and provide high-quality population data essential for sustainable socio-economic development.

Keywords-Artificial Intelligence; Population Census; Data Accuracy; Operational Efficiency; Digital Demography; Nigeria

INTRODUCTION

A population census is universally recognized as the cornerstone of demographic data systems, providing an empirical foundation for policy formulation, governance, and sustainable development. The United Nations (UN) defines a population census as “the total process of collecting, compiling, evaluating, analysing and publishing demographic, economic and social data pertaining, at a specified time, to all persons in a country” (United Nations Statistics Division, 2022). It serves as the most comprehensive source of information on a country's population size, spatial distribution, structure, and socio-economic characteristics, forming the basis for decision-making in areas such as infrastructure development, education, healthcare, and political representation (World Bank, 2021). Globally, countries rely on census data to allocate resources, plan public services, and monitor progress toward the Sustainable Development Goals (SDGs). For instance, in Canada, the 2021 Census guided national strategies on housing and social inclusion (Statistics Canada, 2022). Similarly, the United States employs decennial census data to apportion congressional seats and federal funding (U.S. Census Bureau, 2020). In Nigeria, census data are indispensable for effective governance and equitable resource

distribution. The National Population Commission (NPC) underscores that accurate population figures guide “the determination of fiscal transfers, development planning, and the provision of essential public services” (NPC, 2023). However, successive census exercises in Nigeria have struggled with credibility and completeness, limiting their utility for policy and national planning. Nigeria's census history has been marred by operational, political, and technical challenges that compromise data accuracy and efficiency. The most recurrent issues include logistical constraints, data falsification, political interference, and manual processes. First, logistical and infrastructural limitations hinder enumeration coverage. Nigeria's vast landmass, difficult terrain, and limited transport and communication infrastructure make it challenging to reach remote communities (Afolayan, 2021). Second, data falsification and politicization have been pervasive. Census figures have often been contested due to perceived manipulation for political or ethnic advantage, particularly in the 1962/63 and 1973 censuses (Ezeh & Nwogu, 2020). These disputes have eroded public trust and hindered the institutionalization of regular census schedules. Third, manual data collection processes contribute to inefficiency. The 2006 census relied heavily on paper-based enumeration and manual data entry, resulting in duplication, slow processing, and high

error margins (Okonjo, 2022). Finally, delays and irregularity have characterized Nigeria's census operations. Nearly two decades have elapsed since the last national census, leaving policymakers to rely on projections rather than current figures (National Bureau of Statistics [NBS], 2023). The absence of up-to-date demographic data undermines Nigeria's Vision 2050 development goals and the precision of socio-economic planning. Globally, national statistical systems are embracing Artificial Intelligence (AI) to modernize census processes. AI, through machine learning, computer vision, and natural language processing, enhances data collection, validation, and analysis. The U.S. Census Bureau has explored AI-based automation in address validation and fraud detection to improve operational efficiency (U.S. Census Bureau, 2023). Similarly, Statistics New Zealand integrates AI algorithms to merge administrative records with traditional census data for greater accuracy and cost-effectiveness (Stats NZ, 2021). In developing contexts, AI has proven transformative in addressing enumeration gaps. The United Nations Economic Commission for Africa (UNECA) reported that AI and geospatial technologies significantly improved mapping and enumeration in pilot censuses across Kenya, Ghana, and Rwanda (UNECA, 2022). Additionally, India's 2021 Digital Census initiative incorporated AI-enabled face recognition and cloud-based data validation systems to enhance data reliability (Government of India, 2021). These global experiences demonstrate that AI can strengthen demographic data integrity by automating repetitive tasks, detecting inconsistencies, and providing real-time data analytics thereby improving both accuracy and efficiency in census operations. In the Nigerian context, adopting AI in census operations offers a viable pathway to overcome long-standing logistical, political, and technical barriers. The National Population Commission has signaled its intent to conduct a "digital-first census," integrating GIS and real-time data transmission technologies (NPC, 2023). Incorporating AI would further enhance this vision through:

- i. Automated geospatial mapping using AI-driven satellite imagery to identify settlements and track population movements (Esri, 2022);
- ii. Data validation and de-duplication through machine learning algorithms that detect anomalies and inconsistencies in collected data;
- iii. Predictive analytics for demographic projections and real-time monitoring of enumeration progress;
- iv. Operational optimization via AI-based logistics planning and chatbot-assisted enumerator support. By leveraging these applications, Nigeria can improve census data reliability, reduce human error, accelerate result publication, and build institutional confidence in demographic statistics.

Statement of the Problem

Despite widespread recognition of the importance of census data, Nigeria's national censuses continue to face reliability challenges due to outdated methodologies and human-induced

errors. While AI has revolutionized census management globally, its integration into Nigeria's census framework remains limited. The critical problem is the persistent inaccuracy, inefficiency, and irregularity of census data, which hinders evidence-based policy and equitable development. Consequently, there is a need to conceptually examine how AI can enhance the accuracy and operational efficiency of Nigeria's census process.

Objectives of the Study

The main objective of this conceptual review is to assess the application of Artificial Intelligence in improving the accuracy and efficiency of national population censuses in Nigeria. The specific objectives are to:

1. Examine the importance of accurate census data for Nigeria's national planning.
2. Identify the persistent challenges affecting census accuracy and efficiency in Nigeria.
3. Review global experiences of AI applications in census and population data management.
4. Explore potential applications of AI across Nigeria's census operations.
5. Discuss the implications, opportunities, and constraints of adopting AI in Nigeria's census framework.

Conceptual Scope and Limitations of the Review

This study is a conceptual review, relying on secondary data and literature to explore the intersection between Artificial Intelligence and census administration. It focuses on the potential of AI tools in improving the accuracy (data validity, completeness, consistency) and efficiency (timeliness, cost-effectiveness, logistics) of Nigeria's population census. However, since it is non-empirical, the review does not test specific AI models in field conditions. The analysis is bounded by existing literature, institutional data, and international experiences. The findings thus serve as a conceptual framework for policymakers, scholars, and practitioners seeking to integrate AI into Nigeria's future census strategy.

Conceptual Clarifications

Artificial Intelligence (AI) refers to the capability of computer systems to perform tasks that typically require human intelligence, such as learning, reasoning, problem-solving, perception, and natural language understanding (Russell & Norvig, 2021). In practical terms, AI encompasses various subfields including machine learning, deep learning, natural language processing (NLP), computer vision, and robotic process automation (RPA). These technologies enable machines to analyze vast amounts of data, recognize patterns, and make informed predictions or decisions (Haenlein & Kaplan, 2019). In the context of population census operations, AI can automate data collection, verification, and analysis enhancing both accuracy and operational efficiency (United Nations Statistics Division [UNSD], 2023). For instance, AI-

driven geospatial tools have been used in the United States Census Bureau and India's digital census initiatives to identify population clusters, detect duplicates, and improve real-time data validation (U.S. Census Bureau, 2022; Government of India, 2021).

Meaning and Objectives of a Population Census

A population census is the systematic enumeration of all persons within a defined territory at a specified time, typically conducted every ten years (United Nations, 2017). Its primary objective is to generate reliable demographic, social, and economic data necessary for planning, governance, and resource allocation. According to the United Nations Principles and Recommendations for Population and Housing Censuses, the census provides the most comprehensive source of data for understanding the size, distribution, and characteristics of a country's population (UNSD, 2017). In Nigeria, the National Population Commission (NPC) emphasizes that census data are critical for evidence-based policymaking, federal revenue sharing, constituency delineation, and national development planning (NPC, 2023). However, persistent issues such as undercounting and political interference have weakened census reliability.

Concepts of Data Accuracy and Operational Efficiency in Census Administration

Data accuracy in census administration refers to the degree to which collected information reflects the true characteristics of the target population without systematic errors or bias (European Statistical System, 2020). Accuracy ensures that the data are valid, complete, and consistent across all enumeration areas. Conversely, operational efficiency relates to the optimal use of resources time, manpower, and technology to conduct the census effectively and within budget (World Bank, 2022). AI has the potential to strengthen both dimensions. For instance, machine learning algorithms can detect inconsistencies in field data, while AI-based image recognition can verify satellite enumeration areas, reducing duplication and manual workload (UN Global Working Group on Big Data, 2023). By combining these tools, national statistical agencies can achieve more precise and cost-effective censuses.

Digital Demography and AI-Driven Population Analytics

Digital demography is an emerging field that uses digital data sources such as mobile phone usage, social media activity, and satellite imagery to study population dynamics (Hilbert, 2020). AI plays a central role in transforming these raw data streams into meaningful demographic insights through predictive analytics and automated modeling. Globally, organizations such as the International Institute for Applied Systems Analysis (IIASA) and UNFPA's Data Innovation Lab employ AI-based tools to estimate migration flows, fertility patterns, and population distribution in real time (UNFPA, 2022). In African contexts, projects like Digital

Earth Africa use satellite data powered by AI to enhance spatial population mapping and census preparedness (Digital Earth Africa, 2023).

Conceptual Link between AI and Census Modernization

The integration of AI into census systems represents a shift from traditional enumeration to intelligent demographic systems. This modernization process involves embedding AI into every stage planning, mapping, enumeration, verification, analysis, and dissemination (UNSD, 2023). By automating these stages, AI enhances data integrity, reduces human error, and accelerates processing time. For Nigeria, AI-driven census modernization aligns with the National Digital Economy Policy and Strategy (NDEPS), which seeks to digitize governance processes and strengthen data systems (Federal Ministry of Communications and Digital Economy, 2022). Thus, adopting AI technologies offers Nigeria an opportunity to transition from manual, politically sensitive censuses to a more transparent, efficient, and evidence-driven process.

THEORETICAL AND CONCEPTUAL FRAMEWORK

Relevant Theories Underpinning AI Application in Data Management

The application of Artificial Intelligence (AI) in census data management is grounded in several established theoretical perspectives, notably the Technology Acceptance Model (TAM), the Diffusion of Innovations Theory (DOI), and Systems Theory. Each of these frameworks provides insights into how new technologies are perceived, adopted, and integrated within complex institutional settings such as national census operations. The Technology Acceptance Model (TAM), developed by Davis (1989), posits that users' behavioural intention to adopt a technology is influenced by two key factors: perceived usefulness (PU) and perceived ease of use (PEOU). These perceptions shape attitudes toward technology and ultimately determine actual system use (Davis, 1989; Venkatesh & Davis, 2000). In the context of population censuses, TAM helps explain how census officials and enumerators respond to AI innovations such as AI-powered mapping, predictive analytics, or automated data cleaning depending on how beneficial and user-friendly they perceive them to be. When AI tools are viewed as efficient and easy to integrate into workflows, adoption rates and effectiveness tend to increase (Holden & Karsh, 2010). Similarly, the Diffusion of Innovations Theory (DOI), formulated by Rogers (2003), provides a lens for understanding how innovations spread within a social system. Rogers identified five attributes that affect the diffusion process: relative advantage, compatibility, complexity, trialability, and observability. This theory has been applied to explain technological diffusion in public administration and national statistical systems (Greenhalgh et al., 2004). In Nigeria's census context, AI adoption is more likely to

succeed when its advantages over manual methods are visible, its use is compatible with institutional routines, and training opportunities allow for experimentation and demonstration of outcomes (Rogers, 2003). Systems Theory complements these perspectives by emphasizing the interdependence among subsystems within an organization (Bertalanffy, 1968). A census operation can be viewed as a system comprising interrelated components planning, mapping, enumeration, data processing, and dissemination. Integrating AI in one component (e.g., data validation) inevitably affects others (e.g., logistics and resource allocation). Therefore, a systems approach is essential to ensure that AI tools are harmonized within the broader operational framework and that feedback loops are established for continual learning and system improvement (Skytner, 2005). Together, these theories establish a foundation for analyzing how technological, social, and institutional factors interact in the adoption and successful application of AI within national census frameworks.

Conceptual Model Linking AI Tools to Census Performance Indicators

Building on the theoretical foundations above, a conceptual model can be developed to illustrate how AI influences key census performance indicators such as accuracy, timeliness, coverage, and cost-efficiency. The model begins with the deployment of AI tools including machine learning algorithms for error detection, natural language processing for automated data validation, and geospatial AI for mapping enumeration areas (United Nations Statistics Division [UNSD], 2023; U.S. Census Bureau, 2022). These tools feed into mediating or enabling factors, such as perceived usefulness and ease of use (TAM), organizational readiness (DOI), and systemic integration (Systems Theory). When these enabling conditions are favourable meaning staff are well-trained, infrastructure is reliable, and institutional policies support innovation—AI interventions can directly enhance census outcomes. For instance, data accuracy improves through automated error detection and duplicate removal (World Bank, 2022); timeliness increases as data processing becomes faster; coverage expands through geospatial mapping and satellite imagery; and cost-efficiency improves by reducing manual labour and field expenses (UN Global Working Group on Big Data, 2023). Feedback loops also exist: as census performance improves, trust in AI increases, which further strengthens adoption and institutionalization of AI technologies (Hilbert, 2020). Thus, the conceptual model emphasizes both the technical and socio-organizational dimensions of AI-enabled census modernization.

A simplified schematic of this model can be expressed as:

> AI Tools → Enabling Factors (TAM, DOI, Systems Integration) → Census Performance Indicators (Accuracy, Timeliness, Coverage, Cost-efficiency) → Outcomes (Reliable Data, Effective Planning, Public Trust). This model aligns with global experiences, such as the use of AI-based

population mapping in India's 2021 Digital Census (Government of India, 2021) and AI-enhanced enumeration in the U.S. 2020 Census (U.S. Census Bureau, 2022), which demonstrated improvements in both speed and data accuracy.

Discussion of Ethical and Institutional Dimensions

Despite its potential, AI integration in census administration introduces significant ethical and institutional considerations that must be addressed to ensure public trust and data integrity. From an ethical perspective, issues of privacy, bias, transparency, and accountability are paramount. AI algorithms can unintentionally reproduce social biases if trained on unbalanced datasets, leading to inaccurate representation of marginalized populations (UNESCO, 2022). Furthermore, census data are sensitive; ensuring compliance with privacy laws and safeguarding against unauthorized data use is critical (European Statistical System, 2020). Transparent communication about how AI tools function and how data are processed fosters public confidence (UNDP, 2023). Institutionally, successful AI adoption requires capacity building, robust infrastructure, and clear governance frameworks. Nigeria's National Population Commission (NPC) and National Bureau of Statistics (NBS) must collaborate with agencies like the National Information Technology Development Agency (NITDA) to ensure technical readiness and legal oversight (Federal Ministry of Communications and Digital Economy, 2022). Continuous investment in human capital particularly training data scientists, geospatial analysts, and AI ethicists is essential to sustain innovation (World Bank, 2022). Additionally, inter-agency coordination and sustainable funding mechanisms are necessary to institutionalize AI within national census operations (Digital Earth Africa, 2023). Ultimately, embedding AI ethically and systematically into Nigeria's census architecture aligns with global best practices and the UN's call for "responsible AI for official statistics" (UNSD, 2023). Such an approach promises not only technical improvements but also institutional modernization toward transparent, efficient, and citizen-trusted population data systems.

GLOBAL PERSPECTIVES ON AI IN CENSUS OPERATIONS

Review of International Experiences

Globally, national statistical systems are increasingly integrating Artificial Intelligence (AI) to improve census efficiency, data validation, and timeliness. In the United States, the Census Bureau has applied AI and machine learning for address validation, record linkage, and automated data processing to enhance accuracy and reduce manual workloads (U.S. Census Bureau, 2023). The Bureau's research on predictive analytics and anomaly detection demonstrates that while automation improves speed, it must be complemented by rigorous data quality checks to avoid systematic undercounts of minority and low-income groups

(Mitchum et al., 2022). In India, the upcoming 2025 Census plans to use a digital-first approach incorporating GIS, satellite imagery, and AI-assisted mapping to identify households and informal settlements (Government of India, 2024). Pilot studies indicate that machine learning applied to satellite data can detect unlisted dwellings, thereby improving coverage and reducing duplication (World Bank, 2023). The digital strategy also aims to shorten the data processing cycle compared to the decade-long lag in previous censuses (OECD, 2022). China's 2020 Population Census provides one of the most comprehensive global examples of AI-supported demographic enumeration. The National Bureau of Statistics integrated administrative and big data sources supported by computational analytics and AI algorithms to cross-validate household records, reduce double-counting, and optimize regional workload allocation (Zhao, 2021). This integration improved coverage and processing speed despite the COVID-19 disruptions (UN Statistics Division, 2022). In Africa, Kenya's 2019 digital census represents a landmark regional example of geospatial and AI integration. The Kenya National Bureau of Statistics (KNBS) utilized GPS-enabled tablets, digital mapping, and automated data synchronization, achieving faster data release and improved frame accuracy (KNBS, 2020). Kenya's success demonstrates the power of combining AI-enabled geospatial data collection with human supervision, paving the way for other African countries (UNECA, 2021).

Lessons Learned from AI Applications

Three key lessons emerge from global experiences:

1. AI enhances data quality only when integrated with ground verification. Computer vision and machine learning models can identify uncounted settlements or anomalies, but on-the-ground validation remains critical for complex living arrangements (World Bank, 2023; U.S. Census Bureau, 2023). Hybrid designs that combine AI-generated insights with targeted field verification yield more accurate outcomes.
2. Institutional readiness determines the success of AI deployment. Countries such as Kenya and China benefited from strong ICT infrastructure, skilled human resources, and legal frameworks for data protection (UN Statistics Division, 2022; KNBS, 2020). Where these conditions were weak, as in several pilot projects in South Asia and West Africa, the improvements were short-lived (OECD, 2022).
3. Ethics, transparency, and bias mitigation are essential. Automated systems can unintentionally perpetuate social and regional inequalities if not carefully designed and monitored. The U.S. Census Bureau's 2020 review found that algorithmic methods can still undercount minorities unless transparency and human oversight are ensured (Mitchum et al., 2022).

Global Best Practices and Innovations

Across international contexts, several best practices in AI-based census operations have emerged:

- i. Hybrid methodology (AI + field verification): The most effective systems, such as those piloted in India and Kenya, use AI for mapping and anomaly detection while retaining enumerators for local validation (Government of India, 2024; KNBS, 2020).
- ii. Satellite imagery and deep learning for dwelling detection: AI models applied to high-resolution imagery have been used by the UN and WorldPop projects to estimate population density and identify unregistered buildings (WorldPop, 2023; UN Statistics Division, 2022).
- iii. Integration of administrative and big data sources: China's census leveraged tax, education, and utility records integrated through AI-driven reconciliation, significantly reducing enumeration cost and time (Zhao, 2021).
- iv. Transparency and open algorithms: The U.S. Census Bureau has published methodological documentation to ensure public trust in its automation pipelines (U.S. Census Bureau, 2023).
- v. Phased implementation and capacity building: Kenya's stepwise adoption of digital enumeration from GIS basemaps to full digital rollout demonstrated that gradual scaling is vital to manage risks and build institutional confidence (UNECA, 2021).

Implications for Nigeria

For Nigeria, the international experiences suggest that adopting AI can significantly improve accuracy, reduce data falsification, and accelerate census processing. However, the effectiveness of AI depends on institutional capacity, data infrastructure, and ethical governance (UN Statistics Division, 2022). Nigeria can draw lessons from Kenya's integrated geospatial-AI model and India's data digitization framework by investing in satellite mapping, AI-based data cleaning tools, and staff training in computational demography (World Bank, 2023). Importantly, local transparency, privacy protection, and multi-agency collaboration are essential for building public trust in AI-driven census modernization.

NIGERIA'S CENSUS LANDSCAPE

Historical Overview of Population Censuses in Nigeria

Population censuses in Nigeria have a long and complex history, tracing back to the colonial period in the early 20th century. The colonial enumerations were largely administrative, focusing on taxation, labour mobilization, and resource planning rather than comprehensive demographic insights. After independence, Nigeria conducted several national censuses, including those in 1962/63, 1973, 1991, and 2006, aimed at informing political representation, planning, and the allocation of federal resources (NPC, n.d.). While these censuses were intended to establish reliable demographic baselines, many were marred by political contestation, methodological inconsistencies, and logistical challenges, which undermined public trust in the results (Eme,

2015). For instance, the 1962/63 census was widely criticized for discrepancies between Northern and Southern regions, and the 2006 census faced accusations of deliberate inflation of figures in certain states for political advantage (Eme, 2015). These historical challenges have had long-term effects, including contentious resource allocation and skewed population-based political representation.

Major Limitations of Past Census Exercises

Nigeria's censuses have consistently struggled with several limitations that have impacted the accuracy, completeness, and credibility of data:

- i. Political interference and manipulation: Political interests have historically influenced census outcomes. Manipulation of figures to favor certain states or regions undermined trust in official counts, making census results a source of political tension rather than purely statistical data (Eme, 2015; NPC, n.d.).
- ii. Operational and logistical constraints: Nigeria's large geographical area, diverse topography, and varying security conditions pose significant challenges to comprehensive enumeration. Field enumerators often face accessibility issues in rural, flood-prone, or conflict-affected areas. Coupled with manual, paper-based data collection, these conditions contribute to errors, undercounts, and delayed processing (NPC, n.d.; NBS, 2023).
- iii. Data accuracy and consistency issues: Past exercises were plagued by duplication, omission, and misclassification, often due to reliance on human enumerators and the lack of robust verification mechanisms (Eme, 2015). This has raised questions about population estimates for planning, policymaking, and budget allocations.
- iv. Outdated data and delayed dissemination: The interval between censuses and the prolonged time needed to validate and release data have made official statistics stale. For instance, despite being conducted in 2006, the data from Nigeria's last census remained the primary reference for over a decade, limiting evidence-based decision-making for development and SDG monitoring (NBS, 2023).

Current Digital and Institutional Readiness

In recent years, Nigeria has made significant strides toward digital transformation in census operations. The National Population Commission (NPC) has publicly articulated plans for a digital census, integrating GIS basemaps, satellite imagery, mobile enumeration devices, and cloud-based data management systems (NPC, 2023). These technological upgrades aim to address historical challenges of inaccuracy, undercounting, and processing delays. The National Bureau of Statistics (NBS) has also expanded its digital capabilities through online data portals and open data frameworks, improving accessibility, transparency, and interoperability across federal, state, and local agencies. These efforts are essential for ensuring that AI tools such as machine learning

for duplicate detection, anomaly analysis, and predictive enumeration can be effectively deployed. On the infrastructure side, Nigeria has experienced rapid growth in internet penetration, mobile connectivity, and ICT adoption, which provides a foundation for digital census operations. However, digital divides remain significant in rural, conflict-affected, and underdeveloped regions, highlighting the need for hybrid systems that allow offline data collection with later synchronization to central databases (NBS, 2023; NPC, 2023). Institutionally, NPC has collaborated with NASRDA (National Space Research and Development Agency) to integrate geospatial data into enumeration planning. External support, such as ICT equipment donations and training initiatives by international partners like the British High Commission, has also strengthened digital readiness, particularly in e-CRVS (electronic civil registration and vital statistics) and census planning (NPC, 2024; NPC, 2025).

Ongoing Initiatives toward Digital or E-Census Preparation

Several concrete initiatives demonstrate Nigeria's shift toward digital and AI-enabled census operations:

- i. GIS-based enumeration area mapping: Satellite imagery and geospatial analysis are being used to demarcate enumeration areas and identify previously unlisted or informal settlements (NPC, 2023; NPC, 2025).
- ii. Tablet-based mobile data collection ("Census Pads"): These devices reduce reliance on paper forms, enable in-field validation, and improve data transmission efficiency (NPC, 2023).
- iii. Cloud-based storage and analytics: Data collected digitally is uploaded to secure servers, allowing real-time monitoring and immediate error detection (NPC, 2023).
- iv. Collaborative partnerships: NPC's work with NASRDA and international donors ensures technical and infrastructural support for pilot projects, staff training, and eventual full-scale deployment of digital census technologies (NPC, 2024; NPC, 2025). These initiatives reflect a gradual, phased approach: piloting, evaluation, and scaling. This strategy allows Nigeria to test digital innovations, integrate AI tools, and build human capacity before nationwide deployment, reducing risk while improving efficiency and accuracy.

Synthesis and Implications for AI Adoption

Nigeria's census history highlights urgent needs for modernization. Legacy issues political interference, logistical constraints, and data gaps underscore the potential value of AI technologies for geospatial mapping, anomaly detection, and automated data validation. Global lessons suggest that AI is most effective when integrated with hybrid verification systems and robust governance structures. The country's growing digital infrastructure, institutional reforms, and ongoing pilot projects create an enabling environment for AI adoption. For successful integration, Nigeria must ensure:

- i. Ethical and transparent use of AI, including bias mitigation and secure handling of sensitive data.
- ii. Capacity building, particularly in AI, geospatial analytics, and digital enumeration technologies.
- iii. Hybrid operational models, combining AI outputs with targeted field verification to ensure accuracy in hard-to-reach areas.
- iv. Sustained institutional support, including ICT infrastructure, multi-agency coordination, and adequate funding (NPC, 2023; NBS, 2023; Eme, 2015). Properly implemented, AI can transform Nigeria's census operations, delivering timely, accurate, and credible population data, which is critical for policy, planning, and development outcomes.

POTENTIAL APPLICATIONS OF AI IN NIGERIA'S CENSUS PROCESS

Artificial Intelligence (AI) offers transformative potential across all stages of census operations, from data collection to analysis and operational management. Given Nigeria's historical census challenges manual processes, delays, undercounts, and data inconsistencies AI can help modernize and streamline the national census while improving accuracy and efficiency (NPC, 2023; NBS, 2023).

1. Data Collection Phase

AI technologies can enhance population mapping and enumeration by leveraging satellite imagery, computer vision, and unmanned aerial vehicles (drones). Globally, countries like India, Kenya, and China have utilized AI-powered image recognition to identify dwellings and settlements, particularly in informal or rapidly urbanizing areas (World Bank, 2023; Zhao, 2021; KNBS, 2020). In Nigeria, AI-assisted satellite imagery can detect previously unmapped communities, while drones can capture high-resolution images in remote or inaccessible regions. Computer vision models can automatically classify dwellings and infrastructure types, providing a dynamic enumeration frame and reducing omission errors. Combining these tools with GPS-enabled mobile devices for enumerators ("Census Pads") ensures that AI-generated insights are cross-verified in the field (NPC, 2023; NPC, 2025).

2. Data Processing and Verification

AI can significantly improve data cleaning, deduplication, and verification. Machine learning algorithms can automatically detect duplicate records, flag inconsistencies, and predict missing values based on patterns in the data. For example, China's 2020 census integrated multiple administrative records and employed algorithms to reconcile discrepancies, achieving higher accuracy and reduced processing time (Zhao, 2021). Similarly, in the Nigerian context, AI could match data from civil registration, electoral rolls, utility records, and survey data to validate census

counts, ensuring that populations are not undercounted or double-counted (NPC, 2023; NBS, 2023).

3. Data Analysis and Interpretation

AI enables advanced demographic analytics, including predictive modeling for population projections and trend analysis. Machine learning models can forecast population growth, migration patterns, fertility, and mortality trends using real-time census data, enabling policy-makers to make data-driven decisions. Additionally, AI-powered dashboards can visualize census results in near real-time, highlighting population densities, age-sex distributions, and regional disparities. Globally, the U.S. Census Bureau and WorldPop have implemented such real-time visualization systems, which allow timely insights for development planning, disaster response, and resource allocation (U.S. Census Bureau, 2023; WorldPop, 2023). In Nigeria, integrating AI dashboards with government planning portals can enhance transparency and accessibility of census data for stakeholders.

4. Data Security and Integrity

AI can strengthen data security and integrity through advanced authentication, anomaly detection, and encryption techniques. Machine learning models can identify suspicious data entry patterns, potential breaches, or tampering attempts in real time (UN Statistics Division, 2022). For Nigeria, where digital census data will be stored and transmitted across multiple platforms, AI-driven cybersecurity systems can protect sensitive personal information and maintain public trust. This aligns with global best practices in census modernization, emphasizing privacy, confidentiality, and ethical data handling (Mitchum et al., 2022; UN Statistics Division, 2022).

5. Operational Efficiency

AI can improve the operational efficiency of census administration in multiple ways:

- i. Logistics Optimization: AI algorithms can plan enumerator routes, allocate resources efficiently, and forecast staffing needs based on population density and regional accessibility (World Bank, 2023).
- ii. AI Chatbots: Automated assistants can guide enumerators, answer procedural questions, and provide real-time troubleshooting during enumeration.
- iii. Monitoring and Supervision: Machine learning can detect deviations from expected data collection patterns, enabling supervisors to address errors promptly (U.S. Census Bureau, 2023). Together, these AI applications can significantly reduce operational costs, improve enumeration coverage, and enhance the overall quality of census outputs in Nigeria (NPC, 2023; NBS, 2023).

Synthesis and Implications

The integration of Artificial Intelligence across the census workflow provides Nigeria with a significant opportunity to modernize its population data systems, improve the accuracy of demographic information, and enhance operational efficiency. Successful implementation, however, depends on several critical factors, including the availability of adequate ICT infrastructure and stable internet access, the development of human capacity through training census staff in AI tools, geospatial analytics, and cybersecurity, and the establishment of robust ethical and legal frameworks to safeguard data privacy and ensure algorithmic transparency. Additionally, the use of hybrid models that combine AI-generated outputs with traditional field verification is essential to mitigate risks of undercounting or bias. By adopting these AI-driven approaches, Nigeria can transform its 2025 census into a digital-first, evidence-based, and reliable population enumeration that aligns with international best practices.

CHALLENGES AND CONSTRAINTS IN APPLYING AI TO NIGERIA'S CENSUS

While AI presents significant opportunities for enhancing the accuracy, efficiency, and timeliness of Nigeria's census, its effective adoption faces several interrelated challenges. These encompass infrastructural, ethical, institutional, financial, and technical dimensions, which must be addressed for successful implementation.

1. Infrastructural Limitations

A major constraint for AI-driven census operations in Nigeria is the limited and uneven ICT infrastructure, particularly in rural and conflict-affected areas. Reliable electricity, broadband internet, and mobile network coverage are critical for digital enumeration devices, cloud-based data storage, and real-time AI analytics (NBS, 2023; NPC, 2023). For instance, while urban centers such as Lagos, Abuja, and Port Harcourt have relatively strong connectivity, many rural regions in Northern Nigeria experience frequent power outages and poor network coverage. These gaps can compromise the deployment of AI-enabled satellite data verification, mobile data collection, and cloud computing, leading to delays, incomplete enumeration, or data loss (UNECA, 2021). Hybrid approaches that combine offline data collection with later synchronization are thus essential but also require careful planning and testing.

2. Data Privacy and Ethical Concerns

The adoption of AI in census processes raises critical privacy and ethical considerations. AI systems often require the integration of multiple data sources such as administrative records, satellite imagery, and mobile survey data to enhance accuracy (UN Statistics Division, 2022). However, improper handling of such data can expose sensitive personal information, erode public trust, and violate legal frameworks. Moreover, AI algorithms can inadvertently introduce bias if

training data are incomplete or unrepresentative. For example, marginalized populations such as nomadic groups, informal settlement residents, and internally displaced persons may be systematically undercounted if models are not carefully calibrated (Mitchum et al., 2022; Zhao, 2021). Ensuring transparency, auditability, and ethical governance of AI systems is therefore crucial for maintaining credibility and public acceptance of Nigeria's digital census.

3. Institutional Capacity and Human Capital Deficit

Nigeria faces gaps in institutional readiness and technical expertise, which constrain the deployment of AI in census operations. AI and machine learning require skilled personnel, including data scientists, GIS specialists, and cybersecurity experts, for system development, monitoring, and maintenance (World Bank, 2023). While NPC and NBS have begun capacity-building programs, there is still a shortage of adequately trained staff who can design, implement, and interpret AI-driven solutions. Without sustained human capital development, the full potential of AI such as predictive modeling, anomaly detection, and automated data cleaning may not be realized, leading to partial or inconsistent digital census outcomes (NPC, 2023; NBS, 2023).

4. Funding and Political Will

AI adoption in census operations demands significant financial investment in hardware, software, cloud services, training, and maintenance. Limited funding and competing national priorities can delay or scale down AI integration (NPC, 2024). Political commitment is equally critical. Past censuses in Nigeria have been vulnerable to political interference, which undermined both accuracy and public trust (Eme, 2015). Effective AI adoption requires bipartisan support, transparent planning, and long-term policy frameworks that insulate census operations from political manipulation while ensuring consistent financing.

5. Algorithmic Bias and Trust Issues

AI models are not neutral; they reflect the biases present in input data and training processes. In the context of Nigeria's census, algorithmic bias could exacerbate historical undercounting of vulnerable groups, such as rural populations, women, and internally displaced persons (Mitchum et al., 2022; Zhao, 2021). Public skepticism of automated systems is another barrier. Communities that distrust technology or fear misuse of personal information may resist participation, reducing coverage and accuracy. Therefore, building trust through transparency, stakeholder engagement, and clear communication of AI processes is essential (UN Statistics Division, 2022).

Synthesis of Challenges

The challenges outlined are interconnected, and effectively overcoming them requires a comprehensive and coordinated approach. This includes investing in ICT infrastructure and reliable power solutions, particularly for rural and underserved areas, as well as establishing strong legal and ethical frameworks to govern data privacy, AI ethics, and algorithmic transparency. Strategic capacity building in AI, geospatial analytics, and digital enumeration for staff at the National Population Commission and the National Bureau of Statistics is also essential. Secured and sustained funding, coupled with political commitment to depoliticize census operations, is critical, alongside public engagement and communication strategies to foster trust and encourage participation. Addressing these constraints is vital for Nigeria to successfully integrate AI into its future digital census, ensuring that demographic data are accurate, timely, and trustworthy for national planning and policy formulation.

IMPLICATIONS FOR POLICY AND PRACTICE

The integration of Artificial Intelligence (AI) into Nigeria's census operations has significant policy, institutional, and operational implications. To realize the potential benefits of AI in enhancing accuracy, efficiency, and reliability, strategic interventions across governance, infrastructure, capacity, and public engagement are necessary.

1. **Strengthening Nigeria's Digital Census Frameworks:** To effectively leverage AI, Nigeria must modernize its census frameworks, transitioning from primarily paper-based operations to fully digital systems. This includes adopting cloud-based data management, GIS-enabled enumeration area mapping, and AI-assisted satellite imagery analysis (NPC, 2023; WorldPop, 2023). A robust digital framework can improve data coverage, reduce manual errors, and enhance timeliness. Lessons from countries such as Kenya, India, and China indicate that integrating AI tools within national statistical systems leads to more accurate population counts and faster dissemination of results (KNBS, 2020; Zhao, 2021; Government of India, 2024). For Nigeria, embedding AI into the National Population Commission (NPC) operational strategy is crucial to institutionalize these technological improvements.

2. **Integration of AI within NPC's Strategic Planning:** AI should be systematically integrated into the National Population Commission's strategic planning and operational procedures to enhance the efficiency and accuracy of census operations. This integration involves deploying machine learning algorithms for tasks such as data cleaning, anomaly detection, and predictive population modeling, as well as utilizing computer vision, drones, and high-resolution satellite imagery to achieve precise enumeration in both urban centers and hard-to-reach areas. Additionally, AI-driven dashboards can provide real-time monitoring, progress tracking, and support informed decision-making. By embedding AI into core census processes, human enumerators are complemented by advanced technologies, reducing the likelihood of undercounting or duplication. Furthermore, AI adoption must

be aligned with national ICT policies, cybersecurity protocols, and ethical guidelines to ensure that data management remains secure, transparent, and responsible.

3. **Capacity Building for Data Scientists and Demographers:** Effective AI integration requires specialized human capacity. NPC and NBS staff, as well as affiliated demographers, statisticians, and GIS specialists, need training in: Machine learning and AI model development for census data processing and predictive analytics, Geospatial analysis for enumeration area mapping and settlement identification, Data security, encryption, and ethical AI practices to maintain public trust and compliance with national and international standards (NPC, 2023; UNECA, 2021). Investment in capacity building should include formal training programs, partnerships with universities, and collaborations with international organizations experienced in AI-enabled census operations (World Bank, 2023; KNBS, 2020). Such programs will ensure that Nigeria has the technical workforce required to operate, monitor, and improve AI-assisted census systems sustainably.

4. **Public Trust, Transparency, and Governance Reforms:** Public acceptance is critical to the success of AI-enabled censuses. Transparency in data collection, clear communication about AI usage, and assurances of privacy and confidentiality are necessary to build confidence among Nigerian citizens (UN Statistics Division, 2022; Mitchum et al., 2022). Policy and governance reforms should focus on: Establishing legal frameworks and ethical guidelines for AI and census data management, Implementing audit and accountability mechanisms for AI algorithms and automated data processing, Promoting community engagement and awareness campaigns to explain the benefits, safeguards, and procedures of AI-assisted enumeration. These measures will foster trust, encourage participation, and ensure that AI-driven census operations are credible, inclusive, and aligned with national development priorities (NPC, 2023; NBS, 2023).

Synthesis and Policy Implications

The implications for Nigeria's policy and practice are significant. Institutional modernization requires embedding digital infrastructure, cloud computing, AI integration, and cybersecurity into the strategic operations of the National Population Commission. Human capital development is equally critical, with training programs for data scientists, GIS analysts, and demographers necessary to sustain AI-driven census processes. Ethical and legal governance must also be prioritized, ensuring data privacy, algorithmic transparency, and audit mechanisms to maintain public trust. In addition, public engagement and advocacy through awareness campaigns and inclusive policies are essential to encourage broad participation and reduce resistance to digital enumeration. By implementing these measures, Nigeria can transform its census into a digital-first, AI-enhanced, and globally benchmarked exercise, delivering accurate and

timely population data vital for national planning, resource allocation, and socio-economic development.

CONCLUSION

This conceptual review has demonstrated that the application of Artificial Intelligence (AI) holds significant potential for enhancing the accuracy, efficiency, and credibility of national population censuses in Nigeria, a context historically characterized by political interference, logistical challenges, undercounting, data inconsistencies, and delays in result dissemination, which have undermined evidence-based policymaking and development planning. The review shows that AI technologies can transform the entire census lifecycle by improving data collection through satellite imagery, drones, and computer vision, strengthening data processing and verification via machine learning techniques that detect duplication and inconsistencies, enhancing data analysis and interpretation through predictive modeling and real-time dashboards, and increasing operational efficiency and data security through automated logistics, monitoring systems, and anomaly detection mechanisms. Despite these benefits, the review underscores that effective AI adoption is constrained by infrastructural deficits, ethical and data-privacy concerns, limited institutional capacity, funding challenges, and the risk of algorithmic bias, all of which necessitate a comprehensive and coordinated response. Evidence from ongoing digital reforms, expanding ICT infrastructure, and institutional strengthening within the National Population Commission indicates that Nigeria possesses a growing level of readiness for AI integration, although success will depend on the strategic alignment of policies, technology, human capacity, and governance frameworks to ensure transparency, inclusiveness, and public trust. Overall, the review concludes that AI represents a strategic opportunity for Nigeria to modernize its census system into a digital-first, efficient, and highly accurate process consistent with global best practices, and that, if responsibly implemented, AI-driven census operations can overcome long-standing challenges, strengthen evidence-based decision-making, and provide timely and reliable population data essential for sustainable socio-economic development.

RECOMMENDATIONS

To fully leverage the potential of Artificial Intelligence (AI) in enhancing the accuracy, efficiency, and reliability of Nigeria's national census, several strategic actions are recommended. These recommendations address policy, institutional, technological, and ethical dimensions, ensuring that AI adoption is both effective and sustainable.

1. Develop a National AI Strategy for Population Data Systems

Nigeria should formulate a comprehensive National Artificial Intelligence strategy specifically focused on population data

systems in order to guide the systematic integration of AI into census operations. Such a strategy should clearly define objectives, implementation frameworks, and monitoring and evaluation mechanisms to ensure effective adoption and measurable outcomes. It should promote the integration of AI tools across the entire census lifecycle, from data collection and processing to analysis and dissemination, while also establishing clear standards for data quality and interoperability to support reliable AI-driven analytics. In addition, the strategy should incorporate provisions for sustainability and scalability to ensure that AI solutions remain adaptable to future demographic dynamics and technological advancements. Overall, a dedicated National AI Strategy for population data systems would provide a coherent roadmap for aligning AI adoption with national development priorities and ensuring coordinated, consistent implementation across relevant institutions and agencies.

2. Enhance collaboration between NPC, NITDA, and Academic Institutions

Strengthening collaboration among the National Population Commission, the National Information Technology Development Agency, and academic and research institutions is critical to advancing Nigeria's capacity to apply Artificial Intelligence in population data systems. Through such partnerships, the National Population Commission can contribute demographic expertise and provide operational oversight of census activities, while the National Information Technology Development Agency can support the development of technical infrastructure, facilitate AI deployment, and strengthen cybersecurity frameworks. At the same time, universities and research institutions can play a vital role in capacity building through training, as well as in the development, testing, and evaluation of AI algorithms tailored to national census needs. Overall, sustained multi-stakeholder collaboration will help ensure that AI solutions for census operations are technically robust, ethically responsible, and contextually suited to Nigeria's diverse demographic and socio-cultural environment.

3. Pilot AI-Assisted Census Mapping and Enumeration Zones

Before full nationwide deployment, Nigeria should implement pilot programmes to test the application of AI-driven tools in census mapping, delineation of enumeration areas, satellite-assisted population identification, and predictive demographic modeling. These pilot initiatives would enable a systematic assessment of technical performance, accuracy levels, error rates, and logistical feasibility under real operational conditions. In addition, pilot studies would provide valuable insights into community acceptance, public trust, and levels of participation, which are essential for achieving comprehensive population coverage. The evidence and lessons generated from these pilots can then be used to refine methodologies, address identified

weaknesses, and inform effective scaling strategies for national implementation while minimizing the risks of operational and technological failures.

4. Ensure Ethical and Legal Frameworks for Data Use

The adoption of Artificial Intelligence in census operations must be supported by robust ethical and legal frameworks designed to protect individual privacy, promote transparency, and prevent the misuse of sensitive population data. Such frameworks should clearly define standards governing data collection, storage, sharing, and the transparency of AI algorithms to ensure responsible data management throughout the census process. In addition, appropriate legal instruments should address issues of citizen consent, data confidentiality, and accountability for errors, misuse, or security breaches arising from AI deployment. The establishment of ethical oversight committees would further strengthen governance by monitoring the design, testing, and implementation of AI systems to ensure compliance with national laws and alignment with internationally accepted best practices. Collectively, these measures would enhance public trust and confidence, thereby encouraging widespread participation in digital and AI-assisted census operations.

5. Continuous Investment in Digital Infrastructure and Human Capacity

Continuous and sustained investment is essential for the successful integration of Artificial Intelligence across Nigeria's census processes. Priority should be given to strengthening digital infrastructure through the expansion of reliable electricity supply, broadband connectivity, cloud computing facilities, and mobile data collection networks to support AI-enabled census operations. Equally important is the development of human capacity through targeted training of demographers, statisticians, geospatial experts, and data scientists who possess the skills required to design, implement, and manage AI-powered systems effectively. In addition, deliberate attention must be paid to the regular maintenance and upgrading of AI models, hardware, and software to ensure that census technologies remain responsive to evolving demographic patterns and rapid technological advancements. Overall, sustained investment in both infrastructure and human capital will underpin the long-term modernization of census operations, enabling the production of accurate, timely, and efficient population data to support effective policymaking and sustainable development planning. Collectively, these recommendations emphasize a strategic, coordinated, and ethically grounded approach to AI integration in Nigeria's census operations. By developing a national AI strategy, fostering collaboration, piloting AI tools, establishing legal frameworks, and investing in infrastructure and human capital, Nigeria can achieve a digital-first, AI-enhanced census that meets international standards and supports evidence-based governance.

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