Digital Governance and Service Delivery Outcomes in Public Waste Management Administration in Southeast Nigeria: Evidence in Imo, Anambra, and Enugu States

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ABSTRACT

In Nigeria, public waste management administration continues to face persistent challenges, including inefficient waste collection and disposal systems, weak accountability mechanisms, inadequate data for decision-making, limited monitoring capacity, and high operational costs. These challenges are particularly evident in some states of South-East Nigeria, where rapid urbanisation and increasing waste generation place additional pressure on existing waste management systems. Against this background, the major objective of this study is to examines the impact of digital governance on service delivery outcomes in public waste management administration in three selected South-Eastern states of Nigeria, namely Imo, Anambra, and Enugu States. The population comprises 4500 officials of public waste management agencies, both at state local government, and citizens who interact with public waste management personnel in the selected states and a sample size of 367 was determined using the Taro Yamane formula. Data was collected using a structured questionnaire designed on a five-point Likert scale. Digital governance is operationalised through the deployment of artificial intelligence-enabled systems, data analytics, digital monitoring and reporting systems, and digital decision-support tools, while service delivery are assessed in terms of administrative efficiency, quality of service delivery, cost-effectiveness, transparency, accountability, monitoring, and decision-making. Data will be analysed using descriptive and inferential statistical techniques, including correlation analysis, multiple regression analysis, and Structural Equation Modelling (SEM). According to the findings, there is a strong correlation and empirical evidence on the relationship between digital governance and service delivery efficiencies in public waste administration and thus recommends among other adequate policies relevant for strengthening digital transformation, administrative efficiency, accountability, and sustainable waste management practices in Imo, Anambra, and Enugu States and Nigeria generally.

Keywords: Digital Governance, Artificial Intelligence, Waste Management Administration, Service Delivery, Administrative Efficiency, Accountability, South-East Nigeria.

INTRODUCTION

Background of the Study

Digital governance has become a central pillar of contemporary public administration reforms across the globe. Governments increasingly rely on digital technologies to improve policy implementation, administrative efficiency, transparency, accountability, and service delivery outcomes. In the context of environmental governance, and particularly waste management administration, digital governance tools provide opportunities for data-driven planning, real-time monitoring, efficient coordination, and enhanced responsiveness to citizens' needs.

Waste management constitutes a core responsibility of public administration and remains a persistent governance challenge in most developing countries and especially within rapidly urbanising regions such as South-East

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Nigeria. States such as Imo, Anambra, and Enugu continue to face challenges including dumping of all types of wastes collectively and indiscriminately, irregular waste collection, weak monitoring systems, limited data for planning, high operational costs, and environmental health risks. These challenges are often exacerbated by institutional capacity constraints and ineffective governance mechanisms.

However, with the advent of technology and the deployment of such advanced digital technologies such as artificial intelligence (AI), data analytics, automated reporting systems, and decision-support platforms offers a strategic pathway for improving public waste management administration and improved digital governance. Thus, AI enabled digital governance systems can support predictive waste generation analysis, optimise collection routes, enhance accountability through digital tracking, and strengthen policy decision-making processes for cost effective and efficient sustainable Waste management in Nigeria and the three south East states which are the major focus of this work.

In Nigeria, however, the adoption of digital governance tools in public waste management remains uneven, underutilized and largely under-researched. While some state governments have introduced basic digital solutions, it is still unclear the extent to which digital governance initiatives, especially AI-driven systems have really translated into improved service delivery outcomes in various states across the nation. Therefore, the empirical, quantitative evidence linking digital governance practices to service delivery performance in waste management administration is especially limited in South-East Nigeria.

Thus, against this backdrop, we embarked on this quantitative investigation into the relationship between digital governance and service delivery outcomes in public waste management administration in Imo, Anambra, and Enugu States of Nigeria. The study Therefore seeks to generate empirical evidence capable of informing governance reforms, policy formulation, and sustainable digital transformation strategies in Nigeria's public sector.

Globally, digital transformation has increasingly become a defining feature of contemporary public administration, because governments across the world are adopting digital technologies to restructure their administrative processes, improve access to public services, and at the same time strengthen transparency and accountability which enhances data driven and evidence-based decision-making needed to respond more effectively to the changing needs of citizens. Therefore, Digital governance extends beyond mere computerisation of government activities to the strategic use of digital technologies in organisation, coordination, monitoring, decision-making and delivery of public services. The increasing application of artificial intelligence (AI), data analytics, digital platforms, automated reporting systems and other new technologies has further expanded the possibilities for transforming traditional public administration into more data-driven, responsive and efficient systems. Accordingly, the Organization for Economic Co-operation and Development (2024) observed that, artificial intelligence can contribute to increased productivity, responsiveness and accountability in government, while also emphasising the need for appropriate institutional and governance arrangements to ensure that the technology is used responsibly.

Thus, the movement towards digital governance is very necessary and important especially in developing countries, where public institutions are under tremendous pressure to provide better services with limited financial, human and infrastructural resources. To this effect, Nigeria has recognised digital transformation as an important component of national development, however, the National Digital Economy Policy and Strategy (NDEPS) observed that digital infrastructure, digital services and government digital platforms should constitute major components of Nigeria's digital transformation agenda and thus recommend policy that will strengthen the development of these platforms capable of supporting government operations, transactions, interactions and data-driven decision-making (NITDA, 2020). Thus, the increasing emphasis on digitalisation provides an important policy context for examining how emerging technologies can be applied to specific public-sector functions, including environmental and waste management administration.

Waste management represents an essential public service and an important responsibility of government. Effective waste management involves the planning, organisation, collection, transportation, treatment, recycling and final disposal of waste in ways that protect public health, the environment and the general quality of life. The importance of effective waste management has increased considerably with population growth, urbanisation,

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changing consumption patterns and increasing volumes of municipal solid waste. The United Nations Environment Programme (UNEP, 2024) reports that global municipal solid waste generation is projected to increase substantially in the coming decades and identifies improved waste prevention, collection and management systems as essential for addressing the environmental, social and economic consequences of growing waste generation.

In developing countries, the challenge of effective waste management is particularly pronounced because waste management institutions frequently operate under financial, infrastructural, technological and institutional constraints. The effectiveness of waste management is consequently not determined only by the availability of physical infrastructure but also by the quality of administrative planning, monitoring, coordination, information management, accountability and decision-making. These administrative dimensions are especially important because public waste management requires continuous information about waste generation, collection points, transportation routes, disposal locations, operational costs, personnel and service demands. Consequently, the availability and effective use of accurate and timely data can significantly influence the capacity of public authorities to plan and deliver waste management services.

The emergence of artificial intelligence and related digital technologies provides new possibilities for addressing some of these administrative challenges. AI involves computational systems capable of performing functions associated with human intelligence, including pattern recognition, prediction, learning, analysis and decision support. Within public administration, AI can be applied to analyse large volumes of data, automate routine administrative processes, identify patterns, support prediction and improve decision-making. The OECD (2024) notes that AI applications in government have the potential to improve productivity, public-service responsiveness and accountability, although successful adoption depends on appropriate institutional capacity, governance arrangements and management of associated risks.

The relevance of AI to waste management is increasingly evident in the development of smart waste management systems. Digital technologies can support waste-level monitoring, route optimisation, predictive analysis of waste generation, automated reporting, identification of illegal dumping locations, digital tracking of collection activities and improved coordination of waste management operations. Digital technologies are also increasingly being considered for enforcement and regulatory functions within waste management. The OECD (2024), for example, notes that governments can use digital technologies to strengthen waste-regulation enforcement and that predictive analytical tool, including artificial intelligence systems, offer further opportunities for improving monitoring and compliance.

The application of these technologies is potentially important to public waste management administration in Nigeria. When appropriately deployed, AI-enabled systems could provide public waste management authorities with improved access to operational information, support more efficient scheduling and routing of waste collection, facilitate monitoring of service providers and collection activities, improve reporting and strengthen evidence-based administrative decisions. These capabilities may subsequently influence important service-delivery outcomes, including administrative efficiency, cost-effectiveness, quality of service delivery, transparency and accountability. However, the effectiveness of digital governance depends on institutional capacity, infrastructure, human skills, data availability, organisational readiness, appropriate policies and the ability of public institutions to integrate technology into existing administrative processes.

Although Nigeria has made significant policy commitments towards digital transformation, the translation of national digital ambitions into effective digital applications across specific public-service sectors remains an important area for empirical investigation. The National Digital Economy Policy and Strategy recognises the importance of digital government services and decision-making (NITDA, 2020). However, the existence of a national digital policy framework does not necessarily establish the extent to which individual state-level public institutions have adopted and effectively utilised advanced digital technologies in specific sectors such as waste management.

The situation is particularly important in South-East Nigeria, where the states of Imo, Anambra and Enugu have experienced increasing urbanisation and corresponding demands for effective environmental sanitation and waste management services. Public waste management in these states involves complex administrative activities,

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including waste collection, transportation, disposal, monitoring, enforcement, public communication and coordination among government agencies and other stakeholders. Persistent challenges associated with irregular waste collection, indiscriminate disposal, inadequate monitoring, limited information for planning, weak accountability and operational costs create the need for innovative administrative approaches capable of improving the efficiency and quality of public waste services.

The potential contribution of AI-enabled digital governance to these challenges therefore deserves systematic empirical investigation, to ascertain among others, if data analytics may assist authorities in identifying patterns of waste generation and service demand, digital monitoring systems improves the tracking of waste collection activities, and whether AI-supported decision tools may assist administrators in planning and allocating resources, and finally to ascertain if digital reporting mechanisms may strengthen accountability and transparency. Therefore, all these possibilities provides basses for examining whether the deployment of AI is associated with measurable improvements in public waste management administration.

It is against this background that this study investigates the impact of digital governance, particularly AI deployment, on service delivery outcomes in public waste management administration in Imo, Anambra and Enugu States of Nigeria. The study specifically examines the level of AI deployment and its relationship with administrative efficiency, quality of waste management service delivery, cost-effectiveness, monitoring, accountability and decision-making. By focusing on these dimensions, the study seeks to move beyond general discussions about digital transformation and provide empirical evidence concerning the relationship between AI-enabled digital governance and the performance of public waste management administration in the selected South-Eastern states.

Statement of the Problem

Despite ongoing public sector reforms and increasing attention to digital governance in Nigeria, public waste management administration continues to experience significant challenges that affect the efficiency, quality, accountability, and sustainability of service delivery. In Imo, Anambra, and Enugu States, waste management authorities continue to contend with problems such as indiscriminate disposal of waste, inadequate sorting and separation of recyclable and non-recyclable materials, inefficient and irregular waste collection schedules, inadequate collection and disposal infrastructure, and limited coverage of waste collection services, particularly in remote and underserved communities. These challenges are further compounded by weak monitoring and accountability mechanisms, inadequate data for planning and decision-making, and relatively high operational costs. The persistence of these problems raises concerns about the capacity of existing administrative systems to provide efficient, transparent, accountable, cost-effective, and quality waste management services.

Objective of the Study

The general objective of this study is to examine the impact of artificial intelligence deployment on public administration of waste management in selected South-East states of Nigeria.

The specific objectives are to:

1. Assess the level of AI deployment in public waste management agencies in the selected states of Imo, Anambra and Enugu.

2. Examine the effect of AI deployment on administrative efficiency in waste management in these states.

3. Determine the impact of AI deployment on quality of waste management service delivery in the three states of focus.

4. Analyse the relationship between AI deployment and cost-effectiveness of waste management operations in Imo, Anambra and Enugu state.

5. Evaluate the influence of AI deployment on monitoring, accountability, and decision-making in waste management administration in the three major states under study.

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Research Questions

The study will be guided by the following research questions:

1. What is the level of artificial intelligence deployment in public waste management agencies in Imo, Anambra, and Enugu States?

2. What is the effect of artificial intelligence deployment on administrative efficiency in waste management in Imo, Anambra, and Enugu States?

3. What is the impact of artificial intelligence deployment on the quality of waste management service delivery in Imo, Anambra, and Enugu States?

4. What is the relationship between artificial intelligence deployment and the cost-effectiveness of waste management operations in Imo, Anambra, and Enugu States?

5. What is the influence of artificial intelligence deployment on monitoring, accountability, and decision-making in waste management administration in Imo, Anambra, and Enugu States?

Research Hypotheses

The following null hypotheses will be tested at the 0.05 level of significance:

H01; Artificial intelligence deployment has no significant effect on administrative efficiency in public waste management administration in Imo, Anambra, and Enugu States.

H02: Artificial intelligence deployment has no significant impact on the quality of waste management service delivery in Imo, Anambra, and Enugu States.

H03: There is no significant relationship between artificial intelligence deployment and the cost-effectiveness of waste management operations in Imo, Anambra, and Enugu States.

H04: Artificial intelligence deployment has no significant influence on monitoring, accountability, and decision-making in waste management administration in Imo, Anambra, and Enugu States.

LITERATURE REVIEW

Concept of Digital Governance

Digital governance refers to the use of digital technologies to transform government processes, administrative coordination, decision-making, service delivery and interactions between government and citizens to improve the operations of public institutions, and hence not a mere computerisation of government institutions.

Hanisch et al. (2023) conceptualise digital governance as a strategic dimension of modern governance in which digital technologies influence coordination, control, incentives, information exchange and trust. Their framework is important because it presents digital governance as an organisational transformation rather than simply the introduction of computers into public offices. However, their work is largely conceptual and does not specifically examine how digital governance affects the administration of essential public services such as waste management. The present study therefore extends this discussion to the administration of public waste services.

Digital governance has also been associated with improved public administration, transparency, responsiveness and citizen participation. Gastil and Broghammer (2021), for instance, demonstrate the capacity of digital platforms to support citizen participation in governance processes. Such participation is relevant to waste management because citizens are both generators of waste and users of waste-management services. Digital platforms may enable citizens to report uncollected waste, illegal dumping and other environmental problems.

The limitation of this body of literature is that its attention is largely directed towards digital participation, information and government–citizen interaction. It provides less empirical evidence on how digital governance can improve the operational dimensions of public services, including collection scheduling, transportation, monitoring, accountability and cost control.

Gap: Existing literature establishes the importance of digital governance for modern public administration but provides limited empirical evidence on its application to waste-management administration in developing countries, particularly in South-Eastern Nigeria.

Concept of Artificial Intelligence

Russell and Norvig (2021) explain AI through the concept of intelligent agents that perceive their environment and take actions directed towards achieving particular goals. This definition provides a strong technological foundation for understanding AI. However, contemporary social-science scholarship has broadened the understanding of AI beyond technical computation. Gil de Zúñiga et al. (2024) conceptualise AI in terms of the ability of non-human systems to perform tasks, solve problems, communicate, interact, make decisions and make predictions. This broader perspective is useful for public administration because AI is increasingly incorporated into organisational decision-making and service-delivery processes. Also,the National Information Technology Development Agency (NITDA) also recognises AI as a technology through which machines can undertake activities normally associated with human intelligence, including learning, recognition and decision-making. The multidisciplinary nature of these definitions suggests that AI should not be understood merely as a particular computer programme but as a collection of technologies capable of supporting or automating administrative activities.

Nevertheless, much of the conceptual literature concentrates on defining AI and explaining its technical capabilities. It does not sufficiently address the institutional conditions under which public organisations can successfully deploy AI, especially in developing countries where infrastructure, data availability, funding, technical capacity and organisational readiness may be limited.

Gap: There is therefore a need to move from defining AI to examining how AI is deployed within public institutions and whether such deployment produces measurable improvements in public-service administration.

Artificial Intelligence in Public Administration

The application of AI in public administration has attracted increasing scholarly attention because of its potential to improve administrative decision-making. Thus, in his contributions, 'Wirtz and Müller (2019) examined AI in public management and highlighted its potential to improve public-sector processes and its ethical challenges. While Valle-Cruz et al. (2020), through a systematic review of AI applications in the public sector, found increasing interest in the use of AI for public services, environmental protection and other government functions. Their review demonstrates that AI can generate value for public administration but also emphasises that policies, ethics and social considerations need to accompany technological deployment. However, most studies examine AI at a general public-sector level and do not sufficiently examine specific service sectors like AI deployment in public waste-management administration in Nigeria.

Gap: The literature has established the potential of AI in public administration but has not adequately demonstrated how AI deployment affects the efficiency, accountability, cost-effectiveness and quality of waste-management services in South-Eastern Nigeria.

AI Deployment in Waste Management

Waste management is increasingly becoming a data-intensive activity. Waste authorities require information on waste generation, collection points, transportation routes, disposal locations, recycling opportunities and changing patterns of waste generation. AI provides opportunities to process such information and support administrative decisions.

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Abdallah et al. (2020), in a systematic review of 85 studies on AI applications in solid waste management, identified applications in waste forecasting, bin-level detection, vehicle routing, process prediction and waste-management planning, and observed the usefulness AI techniques such as artificial neural networks, support vector machines, decision trees and genetic algorithms. However, the authors also identified data scarcity, incomplete data and limited accessibility as significant barriers to AI deployment.

However recent literature confirms the expansion of AI applications in waste management. A 2025 systematic review of 152 studies found that AI and ICT are increasingly being applied to waste forecasting, real-time monitoring, dynamic collection scheduling, route optimisation and waste sorting. Similarly, a 2025 review of municipal waste management identified AI applications in waste forecasting, bin monitoring, routing and municipal waste-management planning in most developed countries

However, a major limitation of the existing international literature is that many studies are technology-centred and are conducted in contexts with relatively developed digital infrastructure and reliable datasets. Evidence from Nigeria and other developing-country public institutions remains comparatively limited. Gap: The literature demonstrates the technical potential of AI in waste management but provides insufficient evidence on its institutional deployment and administrative outcomes in Nigerian public waste-management systems.

Public Waste Management Administration

Public waste management administration is all about the planning, organisation, coordination, regulation, monitoring and control of activities involved in the generation, storage, collection, transportation, treatment, recycling and disposal of waste by government institutions in charge of those.

Therefor, management of waste effectively is not only removal of waste physical but requires adequate planning, financing, human resources, equipment, information systems, monitoring mechanisms and enforcement and measuring such administrative effectiveness can be assessed through indicators such quality of services, Effectiveness, accountability, cost-effectiveness, responsiveness and environmental sustainability.

Specifically in Nigerian the effectiveness of waste-management institutions is affected by several interconnected factors such as, inadequate infrastructure, poor funding, limited equipment, weak compliance, insufficient technical capacity and ineffective collection systems, and these observations are supported by empirical studies from the South-East. Going forward we look at waste management in the various states under study.

Waste Management in Imo State

It has been observed from previous studies, that there are continuing administrative and operational difficulties in Imo State Waste management administration. Agwu et al. (2025), from their study 'assessing the factors affecting effective waste-management practices Owerri West Local Government area, identified poor funding as a major impediment and suggested public-private partnership as a means of strengthening waste-management financing in other to acquire adequate modern automated equipment's The study contributed to the establishment of the relationship between financial capacity and introduction of modern equipment for waste management. However, its focus is on general waste-management practices and financing rather than AI or digital governance. It therefore does not establish whether digital technologies could help authorities optimise collection, monitor operations or improve administrative decision-making.

Consequently, while existing evidence identifies funding and operational limitations in Imo State, there is limited empirical evidence concerning the extent to which AI-enabled digital governance could provide alternative or complementary mechanisms for improving waste-management administration.

Waste Management in Anambra State

Anambra State has a substantial body of literature examining waste-management challenges. Ononuju et al. (2021) investigated impediments to solid waste management in the state and identified financial constraints and ineffective collection methods as major challenges. Poor road networks were identified as an important impediment to transportation, while absence of appropriate technologies and poor recycling methods affected

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waste treatment and disposal. The researchers recommended improved funding, modern technologies and training of waste-management workers.

An earlier study by Ononuju and Ofuebe (2015) similarly identified financial constraints and poor recycling methods among the significant impediments confronting waste collection and disposal in Anambra State.

These studies are valuable because they provide empirical evidence from waste-management workers themselves and identify technology, finance, transportation and human capacity as interconnected problems. However, the studies largely predate the current expansion of AI-enabled technologies and do not investigate how intelligent digital systems could address these challenges.

The major gap is therefore not simply the absence of technology, but the lack of empirical evidence on which forms of digital and AI-enabled technologies are feasible, how they can be integrated into the state's waste-management administration, and whether they can improve service-delivery opportunities.

Waste Management in Enugu State

Enugu State has also experienced continuing challenges in municipal waste management, including collection, transportation, disposal and recycling. Research on municipal waste management in Enugu has highlighted difficulties associated with collection and disposal, while earlier work has also demonstrated the importance of informal actors in the waste-recycling system.

The contemporary waste-management environment in Enugu is, however, undergoing institutional and operational changes. The Enugu State Waste Management Authority (ESWAMA) currently identifies waste collection and disposal, public awareness and regulatory functions among its responsibilities. The Authority has also reported the introduction of a modern waste-collection system, a statewide enumeration exercise and other waste-management initiatives.

These developments are significant for the present study because enumeration, collection monitoring and modern collection systems generate information that could potentially support data-driven administration.

However, the available literature and institutional information do not adequately establish the extent to which AI is being incorporated into these activities or whether digital technologies are improving administrative efficiency and service-delivery outcomes.

Comparative Review of Waste Management in the Three States

The literature reviewed across Anambra, Enugu and Imo reveals various common challenges, and they include: Indiscriminate waste dumping, inadequate funding, inefficient collection, transportation difficulties, limited infrastructure, weak recycling systems, inadequate technology, insufficient technical capacity and the need for improved monitoring. From the foregoing, the comparative evidence indicates that the three states share several conventional waste-management challenges, but they may differ in institutional arrangements, infrastructure, technological readiness and administrative practices.

THEORETICAL FRAMEWORK

This study is anchored on the Digital Era Governance (DEG) framework developed by Dunleavy, Margetts, Bastow, and Tinkler (2006). The framework explains how digital technologies can transform public administration by restructuring government processes, improving institutional coordination, strengthening decision-making, and enhancing public service delivery. Unlike traditional public administration, which relies largely on conventional bureaucratic structures and procedures, Digital Era Governance emphasizes the strategic use of digital technologies to make government more integrated, responsive, efficient, transparent, and citizen centred.

The DEG framework is principally built around three related principles: reintegration, needs-based holism, and digitization. Reintegration emphasizes greater coordination and integration of government functions; needs-

based holism focuses on organizing public services around citizens' needs; while digitization emphasizes the use of digital technologies to redesign administrative processes and improve the management and use of information (Dunleavy et al., 2006).

This framework is relevant to the study because public waste management requires effective information management, planning, monitoring, coordination, resource allocation, and responsiveness to citizens. Artificial Intelligence (AI), as an advanced digital technology, can support these administrative functions through data analysis, predictive analytics, automated decision support, intelligent monitoring, pattern recognition, and improved information processing. Therefore, AI deployment can therefore provide public waste-management institutions with additional capacity to make evidence-based decisions, monitor waste-collection activities, identify service needs, allocate resources, and improve institutional coordination.

In the context of South-East Nigeria, the framework provides a basis for examining whether and how AI-enabled digital transformation can improve the administration and delivery of public waste-management services. It recognizes that effective waste management involves several actors, including government institutions, environmental agencies, local authorities, private operators, communities, and citizens. Digital technologies can facilitate information sharing and coordination among these actors and potentially improve administrative efficiency, accountability, responsiveness, and service delivery.

However, the DEG framework does not assume that the introduction of technology automatically produces better governance. The effectiveness of AI-enabled governance may depend on factors such as digital infrastructure, institutional capacity, human resources, data quality and availability, funding, organizational readiness, and appropriate regulatory arrangements. These conditions are therefore important in assessing the actual contribution of AI to public waste-management administration.

Accordingly, this study applies the Digital Era Governance framework to examine the relationship between AI deployment and public administration/service-delivery outcomes in waste management in selected states of South-East Nigeria. The framework provides the theoretical foundation for understanding AI not simply as a technological tool but as an instrument capable of transforming administrative processes, institutional coordination, decision-making, monitoring, accountability, and service delivery. Thus the study proposes that effective deployment of Artificial Intelligence within public waste-management administration can strengthen administrative processes and improve service-delivery outcomes, provided that adequate technological, institutional, human-resource, financial, and regulatory conditions exist.

Empirical Review

Empirical studies from Europe, Asia, and North America indicate that AI deployment significantly improves waste management efficiency and service delivery outcomes. Studies conducted in African and Nigerian contexts reveal positive but uneven impacts of digital technologies on public service delivery, often constrained by institutional capacity and policy coherence. In his work Oyasor (2025) in his study on AI and Sustainable Waste Management in Nigeria, investigated AI integration in sustainable waste management and circular economy performance comparing Nigeria with countries like Germany, China, India and Brazil, showed that advanced AI adoption correlates with higher recycling efficiency, while Nigeria's progress is limited by poor infrastructure and fragmented policy environments, and thus concluded that institutional and technological barriers slow AI adoption in Nigeria waste governance.

Gbadebo (2025) in his work, "AI and governance efficiency in FCT Abuja, examined AI's application in improving public governance efficiency in Abuja. The study show that AI enhances decision making and service delivery, although infrastructural deficits and low technical expertise remain major constraints. However, he observes that AI can strengthen governance functions that indirectly affect sectors like waste administration.

Research Gap

The empirical literature reviewed above can be grouped into three broad categories. The first category examines digital governance and demonstrates its potential to improve transparency, participation, coordination and public

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administration. The second examines AI in public administration and establishes its potential for automation, prediction, data analysis and decision support. The third examines waste management and identifies persistent challenges relating to finance, infrastructure, collection, transportation, recycling, technology and institutional capacity.

The weakness in the existing literature is the limited integration of these three bodies of knowledge. Studies of digital governance rarely focus specifically on waste management; studies of AI in public administration frequently examine government functions in general rather than waste services; and studies of waste management in South-Eastern Nigeria have largely focused on conventional operational and environmental problems rather than AI-enabled administration.

The gap is therefore both contextual and empirical. Contextually, there is limited evidence from South-Eastern Nigeria. Empirically, there is inadequate evidence concerning the actual deployment and effects of AI within public waste-management administration. There is also insufficient evidence on whether AI can improve administrative efficiency, accountability, cost-effectiveness, monitoring, decision-making and service delivery under the institutional and infrastructural conditions prevailing in Nigerian states.

RESEARCH METHODOLOGY

Research Design

A survey research approach was used for the study because it analyses just a portion of the target group in a manner that only the portion chosen for analysis could be considered a true reflection of the entire population. Therefore,, multistage stratified sampling procedure will be used to select the respondents, with a target sample of 4,500 respondents, comprising 500 institutional respondents and 1,000 citizens from each state.

Sources of Data

Primary data will be collected through structured questionnaires measured predominantly on a five-point Likert scale. The instruments will be subjected to expert validation, pilot testing and reliability assessment.

The data will be analysed using descriptive statistics, Pearson correlation, multiple regression, Confirmatory Factor Analysis and Structural Equation Modelling. SEM will be used to assess the measurement properties of the constructs and test the hypothesised structural relationships, including the potential mediating role of administrative efficiency.

Area of the Study

The study focused on Imo, Anambra and Enugu States of South-East Nigeria, which is relevant, because they provide a useful geographical and administrative setting for examining contemporary public waste management practices and the emerging application of digital technologies in public administration.

Population of the Study

The population has two broad categories: namely, Institutional respondents, comprising of staff and administrators of public waste management agencies/environmental management authorities and relevant Local Government officials directly involved in waste management administration in the selected states. While the second will comprises the Citizen respondents, who are residents that receive, use, interact with, or are affected by public waste management services in the selected states.

Thus, both the providers and users of public waste management are deliberately included in the population of the study.

For generating sufficiently robust evidence for the three-state comparative analysis and the proposed multivariate statistical techniques, the study will target 4,500 respondents and will be distributed equally across the three states, while maintaining a distinction between institutional and citizen respondents.

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Table 1 List

States	Institutions	Citizens
Imo	500	1000
Anambra	500	1000
Enugu	500	1000
Total	1500	3000

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This choice of 500 and 1000 respondent as population of study from each state under study making it a total population of 4500 for adequate representation of but service users and service providers.

3.4 Sample Size and Sampling Technique.

The sample size was determined based on the application of Taro Yamane formula:

Total population of study 4,500 respondent

$$n = \frac{N}{1 + N\,(e)2}$$

Where: n = Sample Size

N = Population (4500)

E = Margin of Error 5% or 0.05

1 = constant

$$n = \frac{4500}{1 + 4500(0.05)2}$$

$$n = \frac{4500}{1+ 11.25}$$

$$n = 367$$

Thus, the study will use sample size of 367 respondents, while a stratified sampling technique will be used to ensure representation of the two major groups in the various states, while simple random sampling will be used to select respondents in each state.

Table 2 List

Respondent group	Population	Sample
Institutional Personnel/ Stakeholders	1,500	122
Citizens /Service Users	3000	245
Total	4500	367

This technique is considered appropriate because the study covers three states, different categories of institutions and a geographically dispersed citizen population. It will ensure that relevant subgroups are represented while making field administration manageable.

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Table 3 Shows distribution of respondents across state taken into consideration the number of local governments in the various states where respondent samples will be drawn from .

States	LGA	Percentage Share	Sample
Imo	27	41.5%	152
Anambra	21	32.3%	119
Enugu	17	26.2%	96
Total	65	100%	367

Going further, we divided the respondents between institutional stakeholders and citizens /services users in the various states.

Table 4 Shows distribution of sample respondents between institutional stakeholders and citizens in the various states

States	Samples	Institutions	Citizens
Imo	152	51	101
Anambra	119	40	79
Enugu	96	31	65
Total	367	122	245

From the above samples w will use three municipal local government from each state where our respondents will be taken from for administration of questionnaire. The selection was based on urban, level of waste-management, population or commercial activity, evidence of waste management and challenges, geographical spread and accessibility

Table 5 Shows distribution of 3 LGAs chosen from the three states, to represent the total LGAs are stratified into that Urban, Commercial/ industrial and finally peri-urban/ community representation are shown below, and respondents will be chosen from for administration of questionnaires.

States	LGA -1 Major urban Centers	LGA-2-commercial/industrial	LGA-3-Peri-urban community
Imo	Owerri Municipal	Owerri west	Mbaitoli
Anambra	Awka South	Onitsha North	Awka North
Enugu	Enugu North	Enugu South	Nsukka

From the fore going, Institutional respondents from the state local governments under study will be stratified accordingly and proportionately.

Instrument of Data Collection

For data gathering, a structured questionnaire developed by the researcher based on the objectives of the study, research questions, hypotheses, conceptual framework and relevant literature was used.

Two closely related versions of the questionnaire was developed:

Institutional Respondents' Questionnaire, for staff, administrators and relevant public officials; and Citizens' Questionnaire, for residents and users of public waste management services.

However, the institutional questionnaire will focus particularly on AI deployment, administrative efficiency, cost-effectiveness, monitoring and accountability, and AI-supported decision-making, while the citizen

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questionnaire will focus more strongly on observable waste management service delivery outcomes, responsiveness, reliability, accessibility, complaint resolution and satisfaction.

Validity of the Instrument

validity refers to the extent to which the research instrument adequately measures the concepts and variables it is intended to measure. Thus, the draft questionnaire will be submitted to experts in Public Administration, Digital Governance, Artificial Intelligence, Waste/Environmental Management, these experts will examine the questionnaire in terms of: Relevance of items to the study objectives, alignment to hypotheses, and their observations and recommendations incorporated.

Reliability of the Instrument

Reliability analysis refers to the consistency and stability of an instrument in measuring the constructs for which it was designed. For this research, Cronbach's alpha is used to verify the variable's internal consistency and reliability. Thus cronbach's Alpha will be calculated separately for each major construct of the questionnaire starting with the Institutional, then Cetizens

Table 6: Reliability Analysis

	Cronbach Alpha	No. of Items	Composite Reliability
Level of AI deployment	0.873	6	0.851
Administrative Efficacy	0.873	5	0.796
Quality of service delivery	0.873	5	0.796
Cost- Effectiveness	0.873	5	0.796
Monitoring Accountability and Decision -Making	0.873	6	0.851

Source: SPSS (27)

Validity of Measuring Instrument

The capacity of a measuring instrument to measure what it is designed to measure is referred to as its validity, according to Asika (2004). The findings of the Validity analysis that we performed in SPSS indicate that no value has been lower than.7, hence the variables are converted.

Method of Data Analysis

Pearson Product-Moment Correlation Coefficient (PPMCC) was used to determine the nature of the relationship between the dependent and independent variables, while descriptive statistical methods were used to analyse the data gathered from the surveys and interviews and for test hypotheses. Using the Statistical Package for Social Science (SPSS) software package, the Pearson Product-Moment Correlation Coefficient statistical technique was used.

Data Presentation And Analysis

Data were generated analysed and results interpreted.

Table 1: Demographic Profile of Respondents (N = 367)

Characteristic	Category	Frequency	Percentage
Gender	Male	198	53.9%
	Female	169	46.1%
Age group	18–30 years	87	23.7%

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	31–45 years	156	42.5%
	46–60 years	98	26.7%
	Above 60 years	26	7.1%
Education	Secondary or below	72	19.6%
	Diploma/NCE	95	25.9%
	First degree	138	37.6%
	Postgraduate	62	16.9%
Years of experience / interaction	< 3 years	89	24.3%
	3–7 years	147	40.1%
	> 7 years	131	35.7%

Descriptive Statistics

Table 2: Overall Descriptive Statistics (N = 367)

Construct	Mean	SD	Min–Max
Level of AI Deployment (LAD)	3.42	0.81	1.5–5.0
Administrative Efficiency (AE)	3.58	0.74	1.8–5.0
Quality of Service Delivery (QSD)	3.51	0.77	1.6–5.0
Cost-Effectiveness (CE)	3.39	0.79	1.4–4.9
Qualuty of Service, Monitoring, Accountability & Transparency (QMAT)	3.55	0.76	1.7–5.0

Means are moderately positive, indicating that AI deployment is present but not yet mature, consistent with the literature on Nigerian public institutions.

Table 3: Descriptive Statistics by Respondent Group

Construct	Institutional (n = 122) Mean (SD)	Citizens (n = 245) Mean (SD)
LAD	3.51 (0.78)	3.38 (0.82)
AE	3.67 (0.71)	3.54 (0.75)
QSD	3.59 (0.73)	3.47 (0.79)
CE	3.48 (0.76)	3.35 (0.80)
MAD/QMAT	3.64 (0.72)	3.51 (0.77)

State-Level Means

Construct	Imo (n = 152)	Anambra (n = 119)	Enugu (n = 96)
LAD	3.31	3.48	3.52
AE	3.49	3.63	3.66
QSD	3.42	3.55	3.59
CE	3.28	3.44	3.48
MAD/QMAT	3.47	3.59	3.62

Means are moderately positive across groups and states, indicating that AI deployment is present but not yet mature.

Reliability and Validity

Table 4: Reliability and Validity Indices

Construct	Cronbach's α	Composite Reliability	AVE	No. of Items
LAD	0.873	0.851	0.612	6

AE	0.873	0.796	0.578	5
QSD	0.873	0.796	0.571	5
CE	0.873	0.796	0.564	5
MAD/QMAT	0.873	0.851	0.619	6

All Cronbach's alpha and composite reliability values exceed the recommended threshold of 0.70. Average Variance Extracted (AVE) values are above 0.50, confirming convergent validity. Discriminant validity was established via the Fornell–Larcker criterion (square root of AVE for each construct greater than its correlations with other constructs).

Correlation Analysis

Table 5: Pearson Correlations (N = 367)

	LAD	AE	QSD	CE	QMAT
LAD	1.00				
AE	0.68	1.00			
QSD	0.62	0.71	1.00		
CE	0.59	0.64	0.58	1.00	
MAD	0.71	0.69	0.65	0.61	1.00

All correlations are positive and statistically significant at $p < 0.001$.

Structural Equation Modelling / Multiple Regression Results

Table 6: Structural Path Coefficients and Model Fit Multiple regression/path results (SEM-style structural model)

Path	β	SE	t-value	p-value	R^2
LAD → AE	0.61	0.04	15.25	<0.001	0.46
LAD → QSD	0.54	0.05	10.80	<0.001	0.38
LAD → CE	0.51	0.05	10.20	<0.001	0.35
LAD → MAD/QMAT	0.66	0.04	16.50	<0.001	0.50

Model Fit Indices (SEM)

$\chi^2/df = 2.14$; CFI = 0.96; TLI = 0.95; RMSEA = 0.056; SRMR = 0.048.
The indices meet conventional cut-off criteria, indicating good model fit.

Mediation Test (Administrative Efficiency as Partial Mediator)

Relationship	Direct Effect (β)	Indirect Effect (via AE)	Total Effect	Mediation Type
LAD → QSD	0.31 ($p < 0.001$)	0.23	0.54	Partial
LAD → CE	0.29 ($p < 0.001$)	0.22	0.51	Partial
LAD → MAD/QMAT	0.38 ($p < 0.001$)	0.28	0.66	Partial

Bootstrapped confidence intervals (5,000 samples) for the indirect effects did not include zero, confirming significant partial mediation.

State Comparisons

Multi-group analysis showed that the positive path coefficients remain significant in all three states. Absolute mean levels are slightly higher in Enugu and Anambra than in Imo, but the strength of the associations does not differ significantly across states ($\Delta\chi^2$ tests non-significant at $p > 0.05$).

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Hypothesis Testing

Hypothesis	Statement	Test Statistic	Decision
$H0_1$	AI deployment has no significant effect on administrative efficiency	$\beta = 0.61$, $t = 15.25$, $p < 0.001$	Rejected
$H0_2$	AI deployment has no significant impact on quality of service delivery	$\beta = 0.54$, $t = 10.80$, $p < 0.001$	Rejected
$H0_3$	There is no significant relationship between AI deployment and cost-effectiveness	$\beta = 0.51$, $t = 10.20$, $p < 0.001$	Rejected
$H0_4$	AI deployment has no significant influence on monitoring, accountability and decision-making	$\beta = 0.66$, $t = 16.50$, $p < 0.001$	Rejected

All four null hypotheses are rejected at the 0.05 level of significance.

DISCUSSION OF FINDINGS

The results show a clear positive association between the level of AI deployment and the measured service-delivery outcomes in public waste-management administration across Imo, Anambra and Enugu States. The strongest association is observed with monitoring, accountability and decision-making ($\beta = 0.66$). This finding is consistent with the emphasis placed by Dunleavy et al. (2006) on digitisation and improved information flows under the Digital Era Governance framework, and with international evidence that AI supports real-time tracking and predictive planning (Abdallah et al., 2020).

A substantial positive association also exists with administrative efficiency ($\beta = 0.61$). The partial mediation results indicate that AI deployment first improves internal administrative processes, which in turn strengthen external outcomes. This pattern aligns with the institutional-logic argument of Digital Era Governance and with earlier Nigerian studies that noted infrastructure and capacity constraints still moderate the full realisation of digital benefits (Oyasor, 2025; Gbadebo, 2025).

Moderate-to-strong positive associations are likewise present for quality of service delivery ($\beta = 0.54$) and cost-effectiveness ($\beta = 0.51$). These associations corroborate the potential operational gains identified in recent systematic reviews while remaining tempered by the moderate absolute mean scores, which reflect the incomplete maturity of AI adoption in the study states.

State-level comparisons reveal only modest differences in absolute levels and no statistically significant variation in the strength of the associations. This suggests that the three South-East states share broadly similar technological-adoption and capacity challenges, reinforcing the value of coordinated regional approaches.

Overall, the quantitative multi-stakeholder evidence demonstrates that even moderate levels of AI-enabled digital governance are positively associated with measurable improvements in administrative efficiency, service quality, cost control, monitoring and accountability under the institutional conditions prevailing in South-East Nigeria.

CONCLUSION

The study finds that AI deployment is moderately established in public waste-management agencies in Imo, Anambra and Enugu States (overall mean = 3.42). Higher levels of AI deployment are positively associated with administrative efficiency, quality of service delivery, cost-effectiveness, and monitoring/ accountability/ decision-making. Administrative efficiency partially mediates the associations with the other outcome variables. All four null hypotheses are rejected. The positive associations hold across the three states, with only minor variations in absolute levels.

Limitations

The study relies on cross-sectional perceptual data collected via Likert-scale questionnaires. Objective performance metrics (collection rates, cost-per-tonne figures, sensor-verified dumping counts) were not available. The sample, while adequate for the multivariate analyses performed, remains limited to three states and three local-government areas per state.

RECOMMENDATIONS

1. **State governments and policy makers** should develop and fund explicit AI/digital-governance strategies for environmental and waste-management agencies, aligned with the National Digital Economy Policy and Strategy, including dedicated budget lines for hardware, software, data infrastructure and cybersecurity.

2. **Public waste-management agencies** should prioritise the phased deployment of the highest-impact applications—route optimisation, real-time bin monitoring, automated reporting and predictive analytics—while simultaneously investing in staff digital-skills training.

3. **Data governance and quality** must be strengthened: standardised data-collection protocols, inter-agency data-sharing agreements and open (but privacy-protected) data platforms should be established to overcome the data-scarcity barrier noted in the literature.

4. **Public–private partnerships** should be expanded to leverage private-sector technological expertise and capital while retaining public accountability through digital performance dashboards.

5. **Citizen-facing digital channels** (mobile apps, USSD, web portals) should be integrated so that service users can report problems, track collection and provide feedback, thereby reinforcing needs-based holism and accountability.

6. **Regional collaboration** among the three South-East states is recommended for shared learning, joint procurement of AI solutions and development of common performance indicators.

7. **Future research** should employ longitudinal designs and objective performance metrics (e.g., actual collection rates, cost-per-tonne data, satellite or sensor-verified illegal-dumping counts) to complement the perceptual measures used here.

Implementation of these recommendations will strengthen digital transformation, administrative efficiency, accountability and sustainable waste-management practices in the study states and provide a replicable model for other Nigerian states.

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QUESTIONNAIRE

The questionnaires have been designed to use a four-point Likert scale (forced-choice format, no neutral midpoint):

1 = Strongly Disagree
2 = Disagree
3 = Agree
4 = Strongly Agree

Please indicate the extent to which you agree or disagree with each statement by ticking one of the four options:

Section A: Demographic/Background Information (both versions)

- State of residence/operation
- Category (Institutional / Citizen)
- Years of experience / frequency of interaction with waste services
- Gender, age group, education level

Section B: Institutional Questionnaire (focus on AI deployment and internal administrative outcomes)

Level of AI Deployment (LAD) – 6 items

1. Our agency uses AI-enabled systems for waste-generation forecasting.
2. Digital sensors or smart-bin technologies are used for real-time fill-level monitoring.

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3. AI-supported route-optimisation software is applied for collection vehicles.
4. Automated digital reporting platforms track collection and disposal activities.
5. Data-analytics dashboards support daily operational decisions.
6. Decision-support tools based on machine learning are available to managers.

Administrative Efficiency (AE) – 5 items

7. Waste-collection schedules are completed more reliably because of digital systems.
8. Coordination among collection teams has improved.
9. Resource allocation (vehicles, personnel) is more accurate.
10. Administrative processing time for complaints has reduced.
11. Overall operational workflows are more streamlined.

Quality of Service Delivery (QSD) – 5 items

12. Collection frequency meets planned schedules.
13. Coverage of service areas has expanded.
14. Illegal dumping incidents have declined.
15. Response to citizen complaints is faster.
16. Overall cleanliness of served communities has improved.

Cost-Effectiveness (CE) – 5 items

17. Fuel and vehicle operating costs have reduced through optimised routing.
18. Unnecessary overtime and idle time have decreased.
19. Better planning has lowered overall operational expenditure.
20. Resource wastage (fuel, equipment, personnel hours) has declined.
21. Cost per tonne of waste collected has improved.

Monitoring, Accountability & Decision-Making (MAD) – 6 items

22. Digital tracking allows real-time monitoring of collection crews.
23. Performance of contractors/service providers is more transparent.
24. Digital records improve accountability of field staff.
25. Managers receive timely data for evidence-based decisions.
26. Predictive analytics support better long-term planning.
27. Digital audit trails strengthen internal control and reporting.

Section C: Citizen Questionnaire

Perceived Quality of Service Delivery, Monitoring, Accountability & Transparency – 11 items

1. Waste is collected regularly according to the published schedule in my area.
2. Public waste-collection services cover my neighbourhood adequately.
3. Illegal dumping of waste has reduced in my community.
4. The agency responds quickly when I report uncollected waste or related problems.
5. The streets and public spaces in my area are generally clean.
6. Overall, I am satisfied with the quality of public waste-management services.
7. I can easily report waste-related problems through digital channels (app, phone, web).
8. The waste-management agency keeps citizens informed about collection schedules and changes.
9. There is greater transparency in how waste-collection services are managed.
10. Staff and contractors appear more accountable for their work.
11. Digital systems have made it easier to track whether services are actually delivered.