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Stakeholders' Awareness and Readiness Towards Adoption of Artificial Intelligence Platforms in Plastic Waste Management Among Nigerian Cities

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Abstract

Artificial Intelligence (AI) holds significant potential to optimise processes such as waste collection, sorting, and recycling, ultimately reducing plastic pollution and environmental degradation; however, adoption is limited, especially among developing nations. The study examines various stakeholders' awareness and readiness towards the adoption of artificial intelligence platforms in plastic waste management in Nigerian cities. The study involves stakeholders in waste management and residents that were randomly selected from the Federal Capital Territory, Abuja and Lagos State, Nigeria. With 400 respondents, a questionnaire was adopted for data gathering while data analysis was carried out through descriptive statistics such as frequency count, percentage and mean. The finding revealed that 40.2% of the respondents are aware of AI for waste management while 59.8% of the respondents are not aware. The finding revealed that 64.3% of the respondents are willing to learn about AI solutions in waste management and 68.3% of the respondents support the integration of AI-driven waste management. The result showed that the cost of implementation (56.3%) and lack of technical expertise (34.7%) are the major barriers towards the adoption of AI platforms for waste management. The awareness and readiness to adopt AI-driven platforms were found to be generally low; however, there was notable enthusiasm to learn about AI applications, recognizing their potential benefits in waste sorting, tracking, and predictive analytics. There is a need for collaboration among stakeholders to drive innovation and investment in AI-based waste management solutions.

Keywords : Artificial intelligence (AI), Waste, Plastic Waste Management, Plastic Pollution, Nigerian Cities

Introduction

Plastic pollution stands as an urgent global challenge, inflicting detrimental impacts on ecosystems, human health, and economies, particularly pronounced in developing countries like Nigeria where insufficient waste management infrastructure exacerbates the problem (Jambeck et al., 2015; Akpan & Ikpe, 2020; Solaja et. al., 2017). With the annual global production of plastics surpassing 359 million metric tons, and over 8 million tons ending up in the oceans annually, urgent action is imperative (Geyer et al., 2017). Plastic waste not only mars landscapes and clogs waterways but also poses severe threats to wildlife through ingestion and entanglement (Solaja, et. al, 2023). As societies grapple with this crisis, the integration of artificial intelligence (AI) emerges as a promising avenue for tackling plastic waste, leveraging technology to enhance waste management practices. AI, encompassing machine learning, natural language processing, and computer vision, mimics human intelligence in performing tasks, offering innovative solutions to complex problems (Russell & Norvig, 2021). In the realm of waste management, AI holds significant potential to optimize processes such as waste collection, sorting, and recycling, ultimately reducing plastic pollution and environmental degradation (Zheng et al., 2019).

Deploying AI for plastic waste reduction and pollution can help design products and materials that are easier to recycle or reuse by deploying a machine learning algorithm that can analyze complex data sets to identify materials that can be substituted for more sustainable materials. It can also aid identification and sorting of recyclable plastics through image recognition, promoting efficiency and reducing contamination. AI can also predict the maintenance period of recycling equipment, thereby increasing their lifespan and preventing prolonged downtime, to track and analyze the lifecycle of products, from raw materials to disposal, ensuring materials are optimally used and recycled, and waste is minimized as well as to predict demand for recycled materials and their proper disposal. AI technologies such as data analysis can help to develop innovative ways to manage and process plastic waste efficiently by identifying patterns and trends in plastic waste generation and pollution, promoting better decision-making and targeted interventions.

While Artificial Intelligence (AI) holds immense potential in transforming waste management practices, several challenges and limitations need to be addressed for successful implementation (Vyas et al., 2023; Aljawder and Al-Karaghouli, 2022; Bui and Tseng, 2022; Zhang et al., 2019). According to Olawade et al. (2024), some of the key areas of concern include data availability and quality, privacy and security concerns, cost and infrastructure requirements and ethical considerations. However, the trending issues are more peculiar in developed countries where AI-driven waste management is currently practised. For many developing countries, despite increased public awareness and efforts (such as educational campaigns on the effect of plastic pollution, plastic clean-ups of water and land, restrictions and bans on single-use plastics) to reduce plastic pollution, the problem (plastic leakage into the environment, ineffective recycling due to limitations in recycling technologies, weak enforcement of regulations) persists due to inadequate waste management systems and limited implementation of circular economy ideas (Olawade et al., 2024). Considering this, the study examines various stakeholders' awareness and readiness towards the adoption of artificial intelligence platforms in plastic waste management in Nigerian cities.

Artificial Intelligence Techniques in Waste Management

To manage and handle waste efficiently, artificial intelligence (AI) techniques have been widely utilized as highlighted in Figure 1. As a result, it is capable of handling large amounts of waste data, generating efficient and reliable results, while providing the opportunity to automate a variety of processes. Several AI techniques are widely employed in the waste management sector, including waste collection, waste sorting, bin-level sorting, waste treatment, and waste management planning (Chen, 2022; Xiang et al., 2021). There has been a drastic expansion of the use of AI in recent years, and various governments and organizations are continuously investing in different AI innovations. (Abdallah et al., 2020; Yigitcanlar & Cugurullo, 2020). AI technology adoption has soared, and the global market size is forecast to grow from USD 428.00 billion in 2022 to USD 2,025.12 billion in 2030 (FBI, 2023).

Waste collection plays a crucial role in managing waste efficiently and ensuring a clean and sustainable environment (Assef et al., 2022; Kaya et al., 2021). With the advancements in Artificial Intelligence (AI), waste collection processes have been revolutionized by incorporating smart bin systems, route optimization algorithms, dynamic scheduling, and demand prediction models (Sharma & Vaid, 2021). Waste sorting is a critical step in the waste management process, where different types of waste are categorized and separated for appropriate treatment or recycling (Chen et al., 2021). The integration of Artificial Intelligence (AI) technologies in waste sorting has revolutionized this process by improving accuracy, speed, and efficiency (Anitha et al., 2022).

Accurate identification and sorting of waste materials are essential for efficient recycling (Olawade et al., 2024). AI-based systems utilize advanced technologies such as machine learning, computer vision, and spectroscopic analysis to identify and sort different types of materials. Current trends in material identification and sorting involve the integration of AI algorithms with high-resolution cameras, hyperspectral imaging, and advanced sensors (Olawade et al., 2024). Effective waste monitoring is crucial for efficient waste management practices. With the advancements in AI, waste monitoring has undergone significant transformations, enabling real-time data collection, predictive analytics, data-driven decision-making, and the integration of the Internet of Things (IoT) and sensor networks.

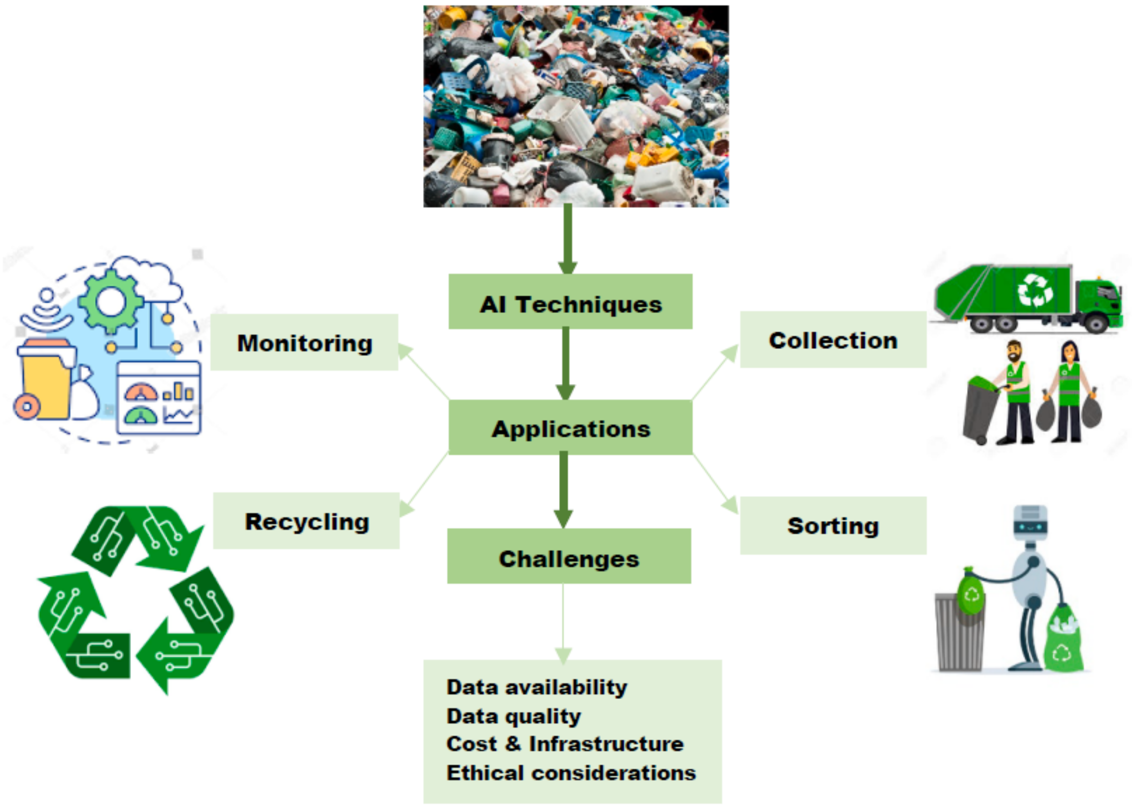

Figure 1: Highlight of Artificial Intelligence Techniques in Waste Management (Olawade et al., 2024)

Methods and Materials

Study Area

The study area, Nigeria (Figure 2) stretches through the 923,769 Km^2 range of which 13,000 square kilometres is covered by water across 36 states from north to south (Merem et al., 2017). The country's large population and rapid urbanization contribute to high waste volumes, while inadequate infrastructure, lack of enforcement, and public awareness hinder efficient collection, treatment, and disposal (Merem et al., 2017). For the study purpose, Lagos State and Federal Capital Territory, Abuja of Nigeria were selected (Figure 2). Abuja, located centrally in Nigeria, is the nation's capital city. Abuja's population currently surpasses 2.5 million people and the population has grown by over 140%, making it the fastest-growing metropolis in Africa and one of the most rapidly expanding globally (Wambebe & Duan, 2020). Lagos, together with its neighbouring metropolis, is Nigeria's largest city and the country's most important economic centre, having the country's major seaports. According to Gbenga (2023), Lagos accounts for 10% of Nigeria's Gross Domestic Product (GDP) and over 90% of Nigeria's trade flow. The city is the fifth largest economy in Africa, having 65% of Nigeria's manufacturing sector. The choice of Lagos and Abuja provides an insight between a highly commercial city and a government-centered city, both grappling with plastic waste issues but within different urban frameworks.

Research Design and Study Population

The cross-sectional survey research method was adopted in carrying out the study. Cross-sectional survey research is a specific type of field study that involves the collection of data from a sample of elements drawn from a well-defined population through the use of a questionnaire (Visser et al., 2002). The population of the study comprised of individuals (respondents) representing plastic recycling companies, waste management agencies (private and public), circular economy initiative groups, technology solution providers, environmental regulatory agencies (such as LASEPA, NESREA), community-based waste collectors and informal recyclers and residents involved or affected by waste management initiatives which were randomly selected from the urban area of Abuja (Asokoro, Wuse and Gwarinpa) and Lagos State (Agege, Oworonsoki and Ikotun).

Sample and Sampling Technique

Purposive sampling ensures that the study gathers rich, relevant, and expert insights. Based on the sampling techniques adopted for the study, four hundred (400) respondents were targeted which was equally distributed between Abuja (200 respondents) and Lagos State (200 respondents).

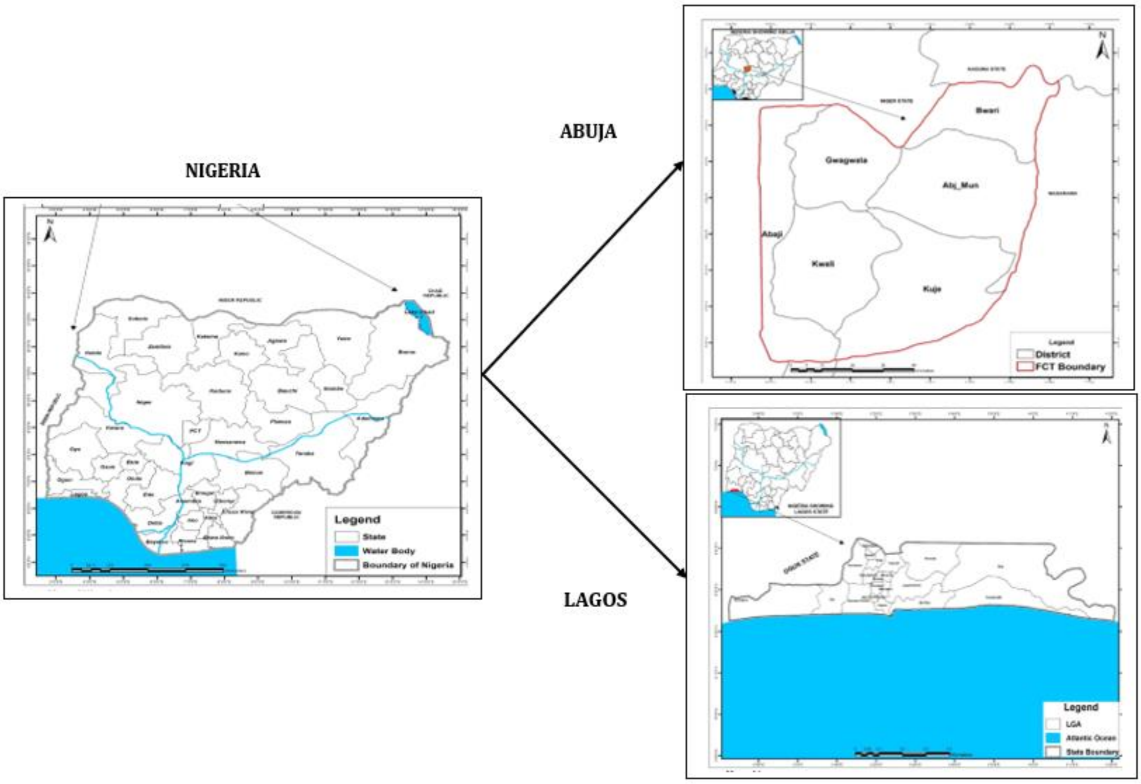

Figure 2: Overview of the Study Area and Selected State (Cities)

Data Collection and Analysis

A questionnaire was used to elicit information from respondents. The questionnaire adopted for the study made use of a closed-ended format. The retrieved questionnaires were coded and subjected to Statistical Package for the Social Sciences (SPSS) for proper analysis. The questionnaire coding was done with MS Excel before being transferred to the Data entry of SPSS. The data were analysed using descriptive statistics such as frequency counts, percentages, mean and charts. The use of such statistics allows the researcher to present the evidence of the study in a way that can be understandable and make a conclusion concerning the variables of the study.

Result

Socio-Demographic Details of the Respondents

The socio-demographic details of the respondents are presented in Table 1. From the analysis, 59.5% of the respondents were male while 40.5% were female. The age range of the respondents showed that 5.3% of the respondents are within the age range of 18-25years, 30.4% are age range of 26-35years, 46.0% are age range of 36-45years while 14.0% and 4.2% of the respondents are within the age range of 46-55years and 56year above respectively. Considering the respondent's occupations, 9.5% of the respondents indicated waste management professional, 6.6% indicated tech/AI specialist, 12.4% indicated environmental agency staff, 17.2% indicated informal waste workers while 39.4% and 14.8% of the respondents are self-employed and other forms of occupations respectively. On educational qualification, 43.4% of the respondents revealed to have attained a bachelor's degree, 18.8% attained a Higher National Diploma (HND), 25.9% attained a Master's degree, 7.4% attained a Philosophy Doctorate (PhD) while 2.9% and 1.6% of the respondents revealed to have attained technical diploma and other educational qualification respectively. Overall, 59.8% of the respondents indicated Lagos State as their city of residence while 40.2% of the respondents indicated FCT, Abuja as their city of residence.

Stakeholders' Awareness and Readiness to Adopt AI-Driven Platforms in Plastic Waste Management

Table 2 presents the respondents' feedback regarding the stakeholders' awareness and readiness to adopt AI-driven platforms in plastic waste management. The finding revealed that 40.2% of the respondents are aware of AI for waste management while 59.8% of the respondents indicated not to be aware of AI for waste management. Among the respondents, 15.3% indicated to be aware of AI-driven waste sorting or recycling technologies while 46.8% and 37.8% of the respondents indicated unaware and not sure of AI-driven waste sorting or recycling technologies. On the aspect of benefit from AI in plastic waste management, 35.2% of the respondents revealed that sorting of waste could benefit from AI in plastic waste management, 26.5% indicated tracking of waste volume, 19.6% indicated prediction of waste generation while 12.7% and 6.1% of the respondents revealed that educating the public and other could benefit from AI in plastic waste management. The finding revealed that 64.3% of the respondents are willing to learn about AI solutions in waste management while 24.3% and 11.4% of the respondents are neutral and unwilling to learn about AI solutions in waste management respectively. The finding revealed that 68.3% of the respondents support the integration of AI-driven waste management while 12.2% and 19.6% of the respondents are neutral and oppose the integration of AI-driven waste management respectively.

Table 1: Socio-Demographic Details of the Respondents

Variable	Frequency (n=378)	Percentage (%)
Sex of Respondents		
Male	225	59.5
Female	153	40.5
Age of Respondents		
18–25 years	20	5.3
26–35 years	115	30.4
36–45 years	174	46.0
46–55 years	53	14.0
56 years and above	16	4.2
Occupation		
Waste Management Professional	36	9.5
Tech/AI Specialist	25	6.6
Environmental Agency Staff	47	12.4
Informal Waste Worker	65	17.2
Self-employed	149	39.4
Others	56	14.8
Education Qualification		
Bachelor's Degree	164	43.4
HND	71	18.8
Master's Degree	98	25.9
PhD	28	7.4
Technical/Diploma	11	2.9
Other	6	1.6
City of Residence		
Lagos State	226	59.8
Federal Capital Territory, FCT	152	40.2

Among the respondents, 46.8% indicated that the government was the major driver of AI platforms for waste management adoption, 11.% indicated private companies while 3.4% and 37.8% of the respondents indicated that non-governmental organisations (NGOs) and joint efforts (public-private partnership) as the major driver of AI platform for waste management adoption. Considering the major barrier towards the adoption of AI platform for waste management, 56.3% of the respondents revealed the cost of implementation as the major barrier towards the adoption of AI platform for waste management, 34.7% of the respondents indicated a lack of technical expertise while 3.4% and 5.6% of the respondents indicated that resistance to change and poor infrastructure are the major barrier towards the adoption of AI platform for waste management respectively.

Discussion

The finding revealed that most of the respondents are not aware of AI for waste management and AI-driven waste sorting or recycling technologies. The outcome indicated a limited awareness of AI-driven platforms for waste management among the respondents. This aligns with Dutta et al. (2022), who found that despite AI's transformative potential, public knowledge about AI applications in waste systems remains low. Research by Raut et al. (2019) emphasized that knowledge gaps act as a critical barrier to technology adoption in sustainable waste systems. The respondents revealed that sorting of waste, tracking of waste volume and prediction of waste generation could benefit from AI in plastic waste management.

Table 2: Stakeholders' Awareness and Readiness to Adopt AI-Driven Platforms in Plastic Waste Management

Variable	Frequency (n=378)	Percentage (%)
Aware of AI for Waste Management		
Yes	152	40.2
No	226	59.8
Aware of AI-Driven Waste Sorting or Recycling Technologies		
Yes	58	15.3
No	177	46.8
Not Sure	143	37.8
Area to Benefit Most from AI in Plastic Waste Management		
Sorting Waste	133	35.2
Tracking Waste Volumes	100	26.5
Predicting Waste Generation	74	19.6
Educating the Public	48	12.7
Other	23	6.1
Willingness to Learn About AI Solutions in Waste Management		
Very Willing	73	19.3
Willing	170	45.0
Neutral	92	24.3
Unwilling	43	11.4
Support for Integration of AI-Driven for Waste Management		
Strongly Support	99	26.2
Support	159	42.1
Neutral	46	12.2
Oppose	74	19.6
Driver of AI Platform for Waste Management Adoption		
Government	177	46.8
Private Companies	45	11.9
NGOs	13	3.4
Joint Effort (Public-Private Partnership)	143	37.8
Major Barrier Towards Adoption of AI Platform for Waste Management		
Cost of Implementation	213	56.3
Lack of Technical Expertise	131	34.7
Resistance to Change	13	3.4
Poor Infrastructure	21	5.6

The outcome is consistent with the studies conducted by Sharma et al. (2021) and Hannan et al. (2021) which demonstrated that AI, through machine learning algorithms, significantly enhances predictive waste management and improves operational efficiency by automating classification and sorting processes. The finding revealed that most respondents are willing to learn about AI solutions in waste management and they support the integration of AI-driven waste management. The outcome corroborates with a study conducted by Menon and Saraswathy (2020) which found that knowledge dissemination and targeted training positively influence stakeholders' readiness to adopt technological innovations. The government and public-private partnerships are perceived as the major driver of AI platforms for waste management adoption. The finding aligns with insights from Yadav and Pathak (2020), who argue that policy incentives, combined with industry collaboration, are critical to scaling AI technologies in waste management. The finding revealed that major barriers towards the adoption of AI platforms for waste management include the cost of implementation and lack of technical expertise. The outcome was similar to those reported by Rejeb et al. (2022), who noted that resource constraints and skill shortages are major hurdles in smart city waste management projects. The findings share similarities with the study conducted by de Sousa et al. (2019) which has identified the cost of implementation and infrastructure requirements and considered ethical implications as part of the challenges and limitations of integrating AI into waste management practices.

Conclusion

With global concern for plastic pollution, the AI-driven approach offers an opportunity for technological support for environmental and economic management of the waste and pollution from various plastic waste activities. Based on the outcome of the study, it was observed that the awareness and readiness to adopt AI-driven platforms for waste management were found to be generally low among respondents. However, there was notable enthusiasm to learn about AI applications, recognizing their potential benefits in waste sorting, tracking, and predictive analytics. Despite this readiness, key barriers such as high costs, technical skill deficits, and weak policy frameworks hinder immediate adoption. The study recommends the need for collaboration between governments, private companies, and research institutions to drive innovation and investment in AI-based waste management solutions and funding of research initiatives that focus on developing low-cost, scalable AI applications tailored to the context of developing countries.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Credit Authorship Contribution Statement

Animashaun-Oshiyemi, A. F.: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Visualization, Project administration, Writing - original draft. **Adesope, O.M., Osuji, L.C.** and **Obafemi, A.A.**: Supervision, Methodology, Validation, Formal analysis, Data curation, Visualization, Review & Editing.

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