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EFFECTS OF ADOPTING INTERNET OF THINGS (IOT) BASED SMART WASTE BIN IN NIGERIA: A REVIEW OF SCHOLARS POSITIONS

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Abstract

The present inherent hurdles to optimising the Internet of Things (IoT) in the Nigerian economy include maintenance and deployment costs, reluctance to change, technological infrastructure, and connection. In order to meet the urgent demand for creative waste management solutions, this study intends to investigate the effects of implementing IoT-based smart garbage bins in Nigeria. The basis for this quasi-experimental study was replies gathered from scholarly publications in the topic by researchers using a Likert scale. The results show that academics are unified in their support of the use of IoT in waste management, pointing to its potential to lower costs, increase efficiency, lessen environmental risks, and create an eco-friendly atmosphere that stimulates economic growth. In line with environmental objectives, scholarly viewpoints also address challenges such as maintenance expenses, technological know-how, residents' adaptation, cybersecurity risks, and incorrect waste disposal. The study suggests that stakeholders, including individuals and government organisations, work together to maintain personal and community cybersecurity, satisfy technology needs, and establish an eco-friendly environment in light of these results. Even if the study's predictions seem bright, further research is still necessary to solve gaps and investigate unexplored areas of IoT-based waste management in Nigeria.

Keywords: Internet of Things (IoT), Nigeria, Waste management, Problems, Prospects

Introduction

The adoption of smart and autonomous technologies in various sectors is growing, aiming to reduce manual labour costs and enhance efficiency. Effective waste disposal, including solid waste and other types, is a critical global concern for environmental preservation and sustainable development (National Policy on Solid Waste Management, 2020). Domestic garbage, including recyclable materials and clinical waste generated in various settings (Islam *et al.*, 2019), and efficient waste management are crucial for industrial sectors like metal, plastic, and glass, as manual waste handling can be unsafe and inefficient. Implementing waste bin management systems and IoT-based waste bins with sensors for automation enhances worker safety and overall process efficiency, boosting productivity and organizational profitability (Bressi *et al.*, 2020; Ghosh, 2019; Han *et al.*, 2016).

Waste management is a critical issue in urban areas worldwide, and Nigeria is no exception. The inefficient waste collection

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and disposal systems in many Nigerian cities have led to environmental and health challenges. Internet of Things (IoT) technology has the potential to revolutionise waste management through the deployment of smart waste bins. These IoT-based smart bins can optimise waste collection, reduce costs, and enhance environmental sustainability.

From the foregoing, the importance of adopting modern technology, in this case, the Internet of Things (IoT), cannot be overemphasized. However, in the adoption of the technology, understanding the prospects and problems of implementing IoT-based smart waste bins in Nigeria is of paramount importance. Hence, this review delves into investigating how the current available systems lack GPS monitoring and fullness alerts for garbage cans, thereby making them suffer from inconsistent sensor behaviour, leading to measurement errors and reduced efficiency in tracking waste volume and decomposition rate. The study will also explore how current available models are limited because their built-in systems' limited capacity to manage devices hinders user control and data retrieval from multiple devices. This will be observed to investigate the feasibility, advantages, and challenges of adopting IoT technology in waste management in the Nigerian context.

The Internet of Things (IoT) integrates physical devices with connections, software, and sensors to collect and share data, while a "smart waste management system" uses technology for streamlined garbage collection and real-time bin-level monitoring. Wireless Sensor Networks (WSNs) consist of sensors that transmit data to a central node. Efficiency involves accomplishing tasks with minimal resource consumption; sustainability focuses on environmental preservation; and optimisation minimises targets within constraints. Real-time monitoring continuously collects data for tasks such as waste management. Sensors respond to environmental cues, and electronic waste bins aid e-waste reclamation. A microcontroller is a compact computer; ultrasonic sensors measure distances with sound waves; weight sensors gauge object weight; infrared sensors detect heat and motion; and servo motors provide precise control over speed and position through motor feedback sensing.

Smart IoT-based waste bins equipped with sensors, motors, and an Arduino microcontroller are being implemented in urban areas to reduce human effort and time spent on waste collection. These bins autonomously move along set paths and can detect obstructions, improving the cleanliness and aesthetics of public spaces (Kamal *et al.,* 2020; Zhu *et al.,* 2021**).** The addition of Global Positioning System (GPS) technology has further enhanced asset tracking and location determination. GPS utilises a network of satellites to determine the device's location, relying on trilateration principles, with at least three satellites needed for accurate positioning (Aaron, 2018; Clement, 2018).

The GPS tracking system is versatile, used for tracking individuals, vehicles, or objects, and can store or transmit location data through cellular, radio, or satellite communication. It offers real-time or post-analysis tracking of assets, thanks to the Global Navigation Satellite System (GNSS) network, which provides navigational data for various journeys (Yadav *et al.,* 2021; Talukdar *et al.,* 2020). GPS tracking devices find application in commercial settings to monitor the movement of goods, with

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options for active tracking, which transmits data to a central database, and inert tracking, which stores data within the device's database (Suresh *et al.,* 2021).

The developmental stages as carried out recently by different groups of individuals will be reviewed in a bid to outline the prospects and possible problems likely to be encountered in the deployment of the technology in waste management in Nigeria, especially as it concerns the use of Internet of Things (IoT) technology. A few of the most promising developments are captured in the next section below.

Materials and methods

This study deviates from traditional quasi-experimental investigations by using a unique methodology. A set of criteria was used to choose fourteen researchers for evaluation, ensuring that they made a substantial addition to the current discussion around waste management and the Internet of Things (IoT). The selection of these researchers was predicated on their standing and compatibility in the scholarly discourse around the rise and practical applications of the Internet of Things. The data used for the investigation came from a comprehensive evaluation of academic publications that were released between 2015 and 2022. Every piece served as a stand-in response, and conclusions were derived from the arguments and viewpoints put forward in the literature. The Likert technique of analysis was utilised to combine these disparate academic viewpoints into a comprehensible and similar framework.

The literature review approach included a critical analysis of the developed waste management systems employing IoT, with an emphasis on their potential for use in major cities, particularly in third-world countries such as Nigeria. The time span of 2015 to 2022 was purposefully chosen to include the most current and relevant breakthroughs in IoT technology. Ethical issues were addressed during the selection and evaluation process, resulting in openness and trustworthiness. The extraction method from academic works required rigorous measures to distil researchers' ideas into Likert scale replies while ensuring uniformity and dependability. The study acknowledges the constraints of the review process and supports the Likert form of analysis while also taking into account the generalizability of findings outside the chosen literature. The suggestions for the adoption of the best technology came from a thorough evaluation of several technologies, taking into account both practical and sociological preferences.

Data presentation

In a bid to promote the use of technology in the management of waste, specifically as it concerns the usage of the internet for things-based waste management, several writers have tried to outline some of the most ingenuity and developments in the field during the implementation process. Most scholars tend to approach the subject from the direction of waste management, as it concerns this study. Such studies as this one were carried out in an attempt to ensure researchers, scientists, and policymakers can use the available studies to improve the practice of waste management, which would guarantee effective waste management practices.

Current trends of Internet of Things (IoT)- based waste management

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Jaiswal et al. (2021) developed an IoT smart waste management system using GPS technology. The system was designed to monitor waste bins in real-time, track their location using GPS, and optimize waste collection routes to reduce collection time and waste management. The authors used an IoT-enabled device, such as an Arduino or Raspberry Pi, to collect data from the sensors placed in the waste bins. In order to track the position of the trash cans and improve the garbage collection procedure, the information gathered was sent through a main server through GPS and GPRS modules. This implies that the integration of IoT and GPS technologies in waste management can lead to tangible benefits. By deploying such systems, municipalities, local government areas in the Nigerian context, and waste management companies can improve service quality, reduce operational costs, and contribute to a more sustainable and environmentally friendly waste management process. Thus, the combination of IoT and GPS in addressing waste management challenges offers valuable insights for future waste management system development.

Employing IoT, GPS, and artificial intelligence technologies, Sarkar et al. (2020) presented a smart garbage management system. The authors created a working model that utilised a sound sensor and a GPS module, respectively, to determine the fill level and position of the trash can. The garbage collection procedure was optimised by the system using an algorithm that employs machine learning to forecast the amount of garbage in each of the trash cans. This system by N. S. Sarkar et al. (2020) presents a promising application of IoT, GPS, and artificial intelligence technologies in the realm of smart garbage management. The development of a working model using a sound sensor and a GPS module to monitor both the fill level and position of trash cans is a notable advancement in the sense that it ensures real-time monitoring of waste bins and efficient collection of targeted waste, following the fact that the integration of machine learning algorithms to predict the volume of garbage in each trash can further enhances the system's effectiveness, making it a valuable tool for optimising waste collection routes and reducing operational costs.

Bhuyan and Sarka (2020) proposed a system using IoT and GPS technologies. The suggested system consists of a smart trash can with sensors to gauge the amount of trash inside, a module that uses GPS to monitor the trash can's location, and a module that uses the GSM network to send data to a single server. The system also comes with a smartphone app that garbage collectors may use to find bins and plan their collection routes. The study found that the suggested strategy might increase waste management's effectiveness. The system developed by Bhuyan and Sarka (2020), that is, an IoT-based smart waste management system, has shown promising results in improving the efficiency of waste collection by providing real-time information and allowing users to report issues. By incorporating GPS technology, it ensures accurate tracking of waste collection vehicles, optimises their routes and reduces unnecessary fuel consumption. Overall, this system contributes to a more streamlined and effective waste management process. Thus, the usage of the Internet of things in the management of waste is foregrounded as a welcome development that should be embraced in modern society owing to the effectiveness of the method as developed by Bhuyan and Sarma.

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Similarly, an IoT-based automated waste handling system was created by Ahmed et al. (2021) that employs GPS technology for garbage collection and disposal. The garbage pickup vehicle and the smart bin are the two primary parts of the system. When the trash level in the smart bin surpasses a predetermined threshold, the smart bin sends a signal to the garbage collection truck to start the waste collection procedure. The smart bin is fitted with sensors that monitor the amount of trash in the bin. A GPS module that records the truck's location and offers current data on the garbage collection process is installed in the waste collection vehicle. The effectiveness of the system in increasing the effectiveness of the method for handling waste has been evaluated and demonstrated.

Earlier and later, developers of Internet of Things (IoT)-based waste management systems shared similar features with the developers discussed above. For example, Khalid et al. (2021) developed an IoT-based smart trash management system that uses GPS technology to optimise waste pickup routes. The system uses a GPS tracking module to locate garbage collection vehicles and an algorithm to optimise waste collection routes based on real-time traffic data. This system reduces waste collection time and improves efficiency.

Al-Fuqaha et al. (2015) highlighted the importance of IoT in developing smart city applications, including waste management. They developed a prototype using a wireless sensor network to collect and transmit data from waste bins, using data analytics and visualisation to optimise waste collection routes. Kumar et al. (2021) and Sharma et al. (2020) developed IoT-based waste management systems that use GPS, sensors, and machine learning algorithms to monitor waste levels and temperature. The systems effectively manage waste collection, reduce operational costs, and promote sustainability. Sharma et al. (2020) also designed a system that uses GPS, RFID, and sensors to improve waste management quality and reduce collection trips.

IoT-based smart trash management systems were created by Zulfiqar et al. (2020) and Khan et al. (2019) that employ GPS and sensor technologies to monitor garbage levels and improve collection routes. While increasing the effectiveness of waste management, these solutions shorten collection times and costs. In addition, Zeng et al. (2018) developed an IoT-based automated waste management system that tracks garbage collection vehicles and optimises collection routes.

Singh et al. (2021) investigated the use of machine learning algorithms to optimise waste collection routes in an IoT-based smart waste management system. The study found that the use of machine learning algorithms was able to reduce the number of collection trips by up to 50%, resulting in significant cost savings and a reduction in carbon emissions. According to Panda *et al.,* (2019) stated that an IoT-based smart waste management system that uses GPS and machine learning techniques to optimise waste collection routes and reduce the cost of waste management The system was developed and tested in a simulated environment utilising Raspberry Pi microcontroller. The proposed approach lowered the time and cost of waste collection while boosting waste management efficiency. A survey done by Mohamed et al. (2020) shows an overview of IoT-based smart waste management systems that use GPS technology. The survey discusses the benefits of these systems, such as improved

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efficiency and reduced costs, and provides a detailed analysis of the different components of a smart waste management system.

Prospects of Internet of Things- based management systems

There is a plethora of reasons why any government in the world, especially Nigeria as a third-world country, should embrace the practice of Internet of Things (IoT)-based waste management systems nationwide. The developed system by Jaiswal et al. (2021) foregrounds the fact that integrating IoT and GPS technologies into waste management systems will not only provide real-time monitoring of waste bins and optimise collection routes, but will also reduce recurrent expenditure in managing waste as it will foster efficient allocation of resources based on real-time data. This will be evident in the dispatching of vehicles only to bins nearing full capacity, thereby minimising unnecessary trips to partially filled bins. Thus, utilising technology-driven solutions in waste management will contribute to cost-effectiveness, sustainability, and overall improvement in waste management practices, particularly in urban areas with high waste generation.

The application of Sarkar et al. (2020) technology to urban cities holds significant promise. Efficient waste management is crucial in densely populated urban areas to maintain cleanliness and reduce the environmental impact of waste disposal. The ability to monitor the fill level of trash cans and predict the volume of garbage allows for the optimisation of collection routes, which can result in more efficient and cost-effective waste collection operations, contributing to the overall cleanliness of urban environments and promoting sustainability.

Similarly to the above-discussed developed systems, the developed systems by Bhuyan and Sarma (2020) and Ahmed et al. (2021) underscore the importance of adopting an Internet of Things (IoT)-based management system in Nigeria. The implementation of advanced waste management systems, featuring smart trash cans with sensor technology and GPS integration, offers multifaceted benefits for urban environments. These systems enhance efficiency by allowing garbage collectors to utilise smartphone apps for optimised collection routes, reducing both collection time and costs. Real-time monitoring of waste bins and collection vehicles enables informed and timely decision-making for more effective waste collection. The automation and optimisation components lead to significant cost reductions, as collection occurs only when smart bins reach specific fill levels, conserving time and fuel resources. Furthermore, the integration of IoT and GPS technology contributes to sustainability by reducing fuel consumption, shortening collection routes, and minimising environmental impact and carbon emissions. Lastly, these advanced systems elevate the overall quality of waste management services, resulting in cleaner urban environments and improved public satisfaction.

Researchers like Khalid et al. (2021), Al-Fuqaha et al. (2015), Kumar et al. (2021), Sharma et al. (2020), Zulfiqar et al. (2020), Khan et al. (2019), Zeng et al. (2018), Singh et al. (2021), Panda *et al.*, (2019), and Mohamed et al. (2020) developed models of the Internet of Things (IoT) share similar prospects to the discussed systems above. These include enhanced operational efficiency through route optimisation and real-time data monitoring, resulting in reduced collection times and lower

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operational costs. These systems promote sustainability by effectively managing waste collection, minimising resource consumption, and reducing carbon emissions, contributing to eco-friendlier urban environments. The cost savings achieved in fuel consumption, labour, and maintenance, combined with the reduction of overflowing bins, not only improve waste management efficiency but also enhance service quality. Integration of advanced technologies such as GPS, RFID, and sensors enhances data accuracy and supports data-driven decision-making for urban waste management authorities, aligning with the broader goals of smart city development and enhancing the overall quality of urban life.

Challenges of Internet of Things (IoT)-based management systems.

Implementing the smart waste management system developed by Jaiswal et al. (2021) in urban areas faces several challenges. These include potential issues related to the availability and reliability of internet connectivity. If a city lacks reliable internet access, real-time monitoring, and data transmission, which are essential for optimising waste collection routes, as in the case of Nigeria, the system may be hampered. The significant upfront and ongoing costs of deploying and maintaining the required technology could be a challenge in a system plagued by systemic budgetary corruption. The resistance to change among residents and waste management personnel, privacy concerns surrounding data collection from waste bins, which some people could consider an invasion of privacy through the surveillance systems, as well as the environmental impact of electronic waste generated by outdated or malfunctioning devices, could represent some counteracting sustainability goals of the waste management system.

Similar to the system developed by Jaiswal et al. (2021), challenges in implementing the system developed by Sarkar et al. (2020) include the substantial financial investment required, which may pose a burden on urban municipalities with budget constraints. Privacy and data security are key concerns due to data collection, necessitating the establishment of regulations and policies to ensure responsible data use. Furthermore, the successful application hinges on resident cooperation for correct usage of smart trash bins and waste collection personnel adapting to new procedures; resistance to change or a lack of awareness could impede the system's effectiveness.

Just like the first two developed technologies, Bhuyan and Sarma (2020) and Ahmed et al. (2021) are not without their challenges and potential problems that could arise in their practical implementations. These could include issues related to the initial costs of deploying such advanced technology, the need for extensive infrastructure, and the integration of these systems with existing waste management practices. Additionally, there might be resistance to change from both residents and waste collection personnel, who must adapt to new procedures and technologies. Privacy concerns related to data collection from smart bins and the environmental impact of electronic waste generated by outdated devices should also be carefully considered. Addressing these challenges will be crucial to successfully implementing these innovative waste management solutions in urban environments.

The results of the previous models discussed with respect to the challenges of

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implementation are akin to those of several other studies. Research and developmental models on Internet of Things (IoT)-based waste management by Khalid et al. (2021), Al-Fuqaha et al. (2015), Kumar et al. (2021), Sharma et al. (2020), Zulfiqar et al. (2020), Khan et al. (2019), Zeng et al. (2018), Singh et al. (2021), Panda *et al.,* (2019), and Mohamed et al. (2020) all suggest that the application of IoT-based waste management systems in urban cities offers numerous advantages but also presents notable challenges. One common challenge is the substantial cost associated with deploying and maintaining these advanced technologies. The initial investment required for IoT devices, sensors, GPS technology, and related infrastructure can strain the budgets of urban municipalities, potentially limiting the widespread adoption of these systems. The need for robust technological infrastructure and connectivity is also identified, stating that urban areas must have reliable internet access and network coverage to support real-time data transmission and monitoring, which is essential for optimizing waste collection routes and enhancing efficiency, a reality not readily present in most third-world developing nations like Nigeria. This is often followed by resistance, as adapting to new procedures and technologies can be met with hesitation, and ensuring a smooth transition is crucial for the success of these innovations. This is because the concern for privacy plays a crucial role, as people are weary of the possibility of being vulnerable through the surveillance systems installed in the waste management gadgets placed in their neighbourhoods.

Table 1: Summary of reviewed scholars

S/N	Reviewed Scholars and Publications	Position
1.	Bressi, S., Sessa, S., & Sgrò, A. (2020) - Internet of Things (IoT) for smart waste management: A systematic literature review. Waste Management	Agree
2.	Han, S., Zhang, Y., Zheng, K., Xu, X., & Liu, Y. (2016) - A survey on the Internet of things: Architecture, enabling technologies, security and privacy, and applications. IEEE Internet of Things Journal, 3(5), 557-586.	Agree
3.	Islam M., Chowdhury, S. and Uddin M. (2020) - "IoT-based smart waste management system using GPS technology. 2020 International Conference on Electrical, Computer and Communication Engineering (ECCE)	Agree
4.	Jaiswal, S., Dixit, S., & Jain, S. (2021) - Design and development of an IoT-based smart waste management system. Journal of Ambient Intelligence and Humanized Computing	Agree
5.	Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015). Internet of Things: A survey on enabling technologies, protocols, and applications. IEEE Communications	Agree

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	Surveys & Tutorials,	
6.	Bhuyan, P. & Sarma, N. (2020). IoT and GPS-based Smart Waste Management System. International Journal of Emerging Trends in Engineering Research	Agree
7.	Panda, R. K., Mahapatra, R. K., & Mohanty, P. (2019). Design and development of an IoT-based waste management system. In 2019 5th International Conference on Advanced Computing & Communication Systems (ICACCS)	Agree
8.	Han, S., Zhang, Y., Zheng, K., Xu, X., & Liu, Y. (2016). A survey on the internet of things: Architecture, enabling technologies, security and privacy, and applications	Agree
9.	Kamal, A. T. M. M., Jahan, M. P., & Al-Mamun, M. A. (2020). Design and development of an IoT-based smart waste management system	Agree
10.	Razaque, A., Ahmed, E., & Elleithy, K. (2018). Smart Waste Management System Using IoT Technologies. IEEE Access, 6, 36629-36640.	Agree
11.	Sarkar, P., Mukherjee, S., & Pal, A. (2020). Internet of Things (IoT)-Based Smart Waste Management System Using Machine Learning Techniques	Agree
12.	Suresh, A., & Arun, N. (2021). Design and Implementation of IoT-based Smart Waste Management System using GPS and Wireless Sensor Networks	Agree
13.	Talukdar, M. F., Bala, B. K., Hossain, M. S., & Rahman, M. A. (2020). IoT-based smart waste management system using GPS for efficient and sustainable waste collection	Agree
14.	Yadav, M., Yadav, N., & Singh, A. (2021). An IoT-based Smart Waste Management System using GPS and RFID Technology	Agree

Result and Discussion

The research report presents a table that summarises the opinions of several experts and provides insight into how they see the Internet of Things (IoT) being integrated into trash management. The collective study makes it clear that researchers generally agree on the benefits of IoT-based waste management systems. The consensus on the advantages—which include improved operational effectiveness, lower costs, and a favourable effect on environmental sustainability—will be covered in detail in this debate.

A recurring element from the perspectives of the researchers is the general recognition of

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the increased operational effectiveness made possible by IoT in the waste management space. Making better decisions is made possible by real-time data collecting and monitoring made possible by the integration of IoT devices. Academics note that waste management agencies can plan maintenance, optimise collection routes, and react quickly to difficulties that may arise because of this real-time information. The general agreement is that one of the main advantages of using IoT in waste management is increased operational efficiency, which streamlines and improves the effectiveness of the entire process.

The beneficial effect of IoT on waste management system cost reduction is another important topic of consensus among experts. Organisations may optimise routes, more effectively distribute resources, and proactively handle equipment failures by utilising IoT technology. Consequently, there is a decrease in operating expenses. The researchers stress that the long-term benefits attained through effective resource utilisation frequently offset the initial investment in IoT infrastructure. The use of IoT in waste management gains a practical component from this common cost-effectiveness standpoint, which makes it an appealing idea for the public and private sectors.

Another area where academics agree on a critical note is environmental sustainability. IoT integration in trash management is consistent with more general sustainability objectives because researchers have all agreed that it may reduce environmental effects. By allowing for the prompt detection and resolution of problems, real-time monitoring helps to stop environmental dangers from getting worse. The paper's study highlights how the carbon footprint of conventional waste management techniques may be significantly reduced by optimising garbage collection and processing using IoT. The argument for the broad use of IoT in trash management as a responsible and progressive strategy is strengthened by this linkage with environmental sustainability goals.

From the above, it is evident that the reviewed scholars agree that the adoption of IoT in waste management offers numerous benefits, including enhanced operational efficiency, cost reduction, and environmental sustainability. The integration of advanced technologies such as GPS, RFID, and sensors enhances data accuracy and supports data-driven decision-making for urban waste management authorities. However, the scholars also acknowledge the challenges associated with the adoption of IoT in waste management, including the need for reliable internet access and network coverage, the substantial cost of deploying and maintaining advanced technologies, and resistance to change and privacy concerns. Overall, the scholars recommend the adoption of IoT-based waste management systems in urban areas, but caution that careful planning and implementation are necessary to ensure success.

IoT-based waste management systems offer numerous advantages: The reviewed literature suggests that IoT-based waste management systems can enhance operational efficiency, reduce collection times and costs, promote sustainability, and contribute to eco-friendlier urban environments. These systems can also improve service quality, enhance data

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accuracy, and support data-driven decision-making for urban waste management authorities.

From the data harvested in the various works of scholarship, several challenges to the implementation of IoT-based waste management systems, including the substantial cost associated with deploying and maintaining these advanced technologies, the need for robust technological infrastructure and connectivity, resistance to change among residents and waste management personnel, privacy concerns surrounding data collection from waste bins, and improper industrial waste disposal and recycling to align with ecological goals. This is in line with the first hypothesis suggesting that the adoption of IoT-based smart waste bins in Nigeria will lead to improved waste disposal efficiency, reduced environmental hazards, and the establishment of an eco-friendly environment that is economically prudent, potentially boosting economic growth by generating revenue, accommodating rising demand, and creating job opportunities through IoT technology adoption

The data from previous research also suggests that GPS and real-time monitoring are essential for optimizing waste collection routes and enhancing efficiency. However, the availability and reliability of internet connectivity can be a challenge in some areas, potentially hampering the effectiveness of these systems. This is in tandem with the second hypothesis which states that the adoption of IoT-based smart waste bins in Nigeria may face challenges related to maintenance costs, technical expertise, citizen adaptability, cybersecurity vulnerabilities, and improper industrial waste disposal and recycling to align with ecological goals, which could hamper the embrace of this modern technology in managing domestic and industrial waste.

The data emphasizes the importance of a collaborative effort among various stakeholders, including government agencies, individuals, and corporations, to successfully navigate the challenges in adopting IoT-based waste management systems. Government agencies should provide financial support, establish regulations, and invest in the necessary technological infrastructure; individuals can contribute to the initiative through responsible waste management practices and data privacy awareness, and corporations should engage with local governments, invest in technology, and demonstrate corporate responsibility by minimizing electronic waste. This is in agreement with the third hypothesis.

Conclusion

This study underscores the transformative potential inherent in the adoption of Internet of Things (IoT)-based waste management systems in Nigeria. The research reveals substantial advantages, encompassing not only cost reduction and efficient waste disposal but also a commitment to environmental sustainability. Despite acknowledging challenges such as maintenance costs, technical expertise, citizen noncompliance, and cybersecurity risks, the paper places strong emphasis on the imperative of collaborative efforts among diverse stakeholders. The pivotal recommendations advocate for proactive government engagement marked by financial support and the establishment of supportive regulatory frameworks. Additionally, the study encourages individual involvement in waste management initiatives, fostering awareness

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about data privacy, while urging corporations to assume responsibility through innovation and the reduction of electronic waste. The significance of advocating for policies that support IoT-based waste management, promoting public awareness, and ensuring a sustained focus on long-term sustainability cannot be overstated. These recommendations, when implemented collectively, hold the promise of a paradigm shift in waste management practices in Nigeria, heralding a future marked by efficiency, sustainability, and positive environmental impact.

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