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AIoT Based Smart Waste Management System

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Abstract: Nowadays waste generated by every household is increasing drastically. So, we need a smarter way for collecting and managing the waste in an efficient manner. This model proposes an AIoT (Artificial Intelligence of Things) aided smart waste management system that leverages various sensors to monitor the level and weight of waste within bins. Upon reaching a predefined threshold, the system triggers an alert to relevant authorities, facilitating timely intervention and efficient waste management strategies. The primary objective of this project is to develop a sophisticated trash bin integrated with sensors and a mobile application. The application serves as a comprehensive platform for waste collection management, enabling users to track collection schedules, automatically segregate plastic waste, and even facilitate payment for garbage disposal services. Each bin is assigned a unique identifier for authorities to monitor its location and take necessary actions. By seamlessly transmitting sensor data to the designated app, this project holds the potential to support initiatives such as Haritha Karma Sena, an endeavor spearheaded by Kudumbasree, thereby streamlining their operations and contributing to a more sustainable waste management ecosystem.

Keywords: AI, IoT, Image processing, ML, Segregation, Waste management.

I. Introduction

The increasing amount of household waste has become a significant concern, primarily due to the widespread use of packaged items, textiles, paper, plastics, metals, and glass. Proper waste management is crucial, and one of the challenges faced is the irregular waste collection schedules, leading to overflowing bins and environmental pollution. To address this issue, the Haritha Karma Sena, an initiative by Kudumbasree, is actively involved in collecting non-biodegradable waste from households. Their efforts aim to reduce the burden on landfills and minimize the environmental impact of improper waste disposal.

However, the existing system faces difficulties in manually recording waste collection data, and there is a need for a more efficient and digitalized solution. This research introduces an innovative approach by incorporating Internet of Things (IoT) technology into waste management. An IoT-enabled smart waste bin is introduced, equipped with sensors to detect the waste level and weight. When the waste in the bin reaches a specific threshold, the system automatically sends an alert to the concerned authorities. Additionally, a web-based platform is developed to facilitate waste collection data entry.

The platform developed for Haritha Karma Sena officials revolutionizes waste collection management by providing real-time monitoring of collection status for each household. With separate logins for users and administrators, it ensures easy accessibility and smooth operation. The accompanying mobile app not only tracks waste collection but also facilitates convenient payment for services. Each bin is tagged with a unique ID, enabling authorities to precisely locate them and respond promptly to any issues. This comprehensive system streamlines waste management processes, improves efficiency, and empowers both users and administrators with valuable insights and tools to maintain cleanliness and sanitation in the community.

In summary, this project presents a holistic solution to the obstacles encountered by organizations like Haritha Karma Sena. Through the integration of IoT technology, a user-friendly mobile application, and a web-based platform, the initiative seeks to optimize waste management procedures, improve data precision, and promote environmental cleanliness. The project aims to enhance efficiency and effectiveness in waste collection, sorting, and disposal, thereby contributing to the creation of a more sustainable and eco-friendly community.

II. Objective

By introducing a sophisticated smart system, it aims to tackle the growing issues linked with household waste production. The primary target is to support Haritha Karma Sena in optimizing the process of garbage collection by introducing intelligent trash bins embedded with sensors. These sensors are designed to play a crucial role by continuously monitoring the level and weight of the waste accumulated within the bins. Once these sensors detect that the waste has reached predetermined threshold values, an automatic alert is instantly transmitted to the authorities. This real-time notification system facilitates swift and precise actions by the concerned authorities, ensuring a proactive and efficient approach to waste management. In essence, the project seeks to leverage the power of AIoT to revolutionize the traditional methods of waste disposal, fostering a smarter and more sustainable solution for handling the increasing challenges posed by household waste generation.

Furthermore, the project aims to enhance user engagement and awareness through the development of a dedicated mobile application. This app serves as a centralized platform to monitor and manage all aspects of waste collection. Users can easily track the status of their waste, receive alerts, and even contribute to environmental sustainability by segregating plastic waste into recyclable and non-recyclable categories. The integration of a payment system within the app further adds a layer of convenience, allowing users to facilitate and streamline the process of garbage collection.

To ensure seamless tracking and management, each smart waste bin is assigned a unique ID, facilitating efficient location tracking by authorities. The collected data from the sensors is transmitted through the app to relevant stakeholders, providing real-time insights into waste levels and patterns. Ultimately, the overarching objective of this project is to significantly ease the burden on Haritha Karma Sena, making waste collection more efficient, environmentally friendly, and contributing to the creation of cleaner and healthier communities.

III. Literature Review

Krishna Mridha [2021] introduced an "Intelligent Based Waste Management Awareness Developed by Transfer Learning" [1]. Employing cutting-edge technology, the waste management system utilizes advanced image recognition to capture and categorize images of targeted waste items, effortlessly sorting them into designated categories. Swift notifications are then dispatched to recycling authorities, facilitating timely and efficient waste disposal processes. It highlights the pivotal role of technology in streamlining waste management operations and promoting recycling practices. By harnessing the power of technology, the system effectively addresses environmental challenges by optimizing resource utilization and minimizing the impact of waste on the ecosystem.

Taneesha Chaudhary [2023] worked on "Design and Development of Smart Waste Management System" [2], presented here revolutionizes garbage collection through smart technology integration. Utilizing ultrasonic sensors, NodeMCU, and a GPS module, intelligent garbage bins are created. These bins detect garbage levels and automatically alert authorities when they are full. Notifications are dispatched via email through platforms like If This Then That (IFTTT) and ThingSpeak. Furthermore, the implementation of a mobile application, built using MIT App Inventor, provides authorities with a powerful tool to monitor the status of bins in real-time and strategize optimal garbage collection routes for efficient disposal. By leveraging this technology, the system not only streamlines waste management processes but also offers a cost-effective and practical solution to address the growing challenges of urban waste. The user-friendly interface of the application ensures ease of use for both administrators and field workers, minimizing the need for extensive training and reducing human errors in data management. With minimal reliance on manual intervention, this AIoT-enabled system demonstrates its economic viability and scalability, making it a promising solution to modernize waste management practices and foster sustainable urban development.

Ayush Parth S. Kumar, Basi Jithendra Sai Kumar, R. L. Bharath *et al.* [2023] worked on "IoT-Based Smart Trash Bin for Real-Time Monitoring and Management of Solid Waste" [3]. The Smart Waste Mechanism (SWM) advocates for an effective waste disposal system by strategically situating Smart Bins (SB) in key locations. These bins, in communication with Trash Collecting Vehicles (TCV), ensure timely waste collection, promoting a cleaner and greener environment through an intelligent and streamlined waste management process. By leveraging IoT technology, this approach minimizes human involvement and streamlines waste management processes effectively.

R. Rathna [2023] introduced "Smart Waste Management Scheme using IoT for Metropolitan Cities" [4]. In the initial phase of the project, the main objective is to create a smart bin system with three distinct compartments tailored for different types of waste: biodegradable household waste, inert debris such as soiled diapers and sanitary napkins, and non-biodegradable waste. The integration of Internet of Things (IoT) technology into waste management facilitates seamless monitoring of these smart bins, allowing for efficient tracking of fill levels and waste composition. This monitoring capability translates into a substantial reduction in the number of trips required by both large and small waste collection vehicles, thereby optimizing the overall waste management process. Furthermore, by minimizing direct contact with waste materials, this innovative approach also addresses health concerns among municipal workers and scavengers, ultimately improving their well-being and safety.

Suresh Kumar V., Siva Sankar S., Sree Rethanya K. [2023] indroduced an "Innovative Waste Management Solutions for Smart Cities using IoT & Nodemcu" [5]. The waste management system encourages proactive participation from users by providing an easy-to-use app for reporting issues. Its architecture, which includes user and admin dashboards along with a mobile app, aims to improve operational effectiveness. Smart bins, equipped with sensors, a WiFi gateway, and a cloud platform, are central to the system's functionality. Additionally, the integration of AI algorithms in future developments holds the promise of further optimizing waste management processes. This advanced solution not only addresses current challenges but also positions itself as a cutting-edge solution for the future, ensuring efficient and sustainable waste management practices.

Dr. T. Sasikala, F. Annie Lincy [2021] introduced an, "Smart Dustbin Management Using IoT and Blynk Application" [6]. It is an innovative smart dustbin, based on the Arduino Uno board and integrated with GSM, GPRS, and sensors, operates by monitoring predefined threshold levels within the bin. When the garbage reaches these levels, continuous alerts are sent to the respective authorities until the issue is resolved, indicated by a red LED. Once the bin is cleared, the LED turns green. If the situation persists for 24 hours without resolution, alerts escalate to higher authorities, ensuring accountability. Additionally, features like maps facilitate locating dustbins, enabling swift response. Inter-bin connectivity fosters efficient communication, creating a smart waste management system. Implementation of these smart dustbins not only promotes hygiene but also minimizes negligence, fostering a clean, disease-free environment in society.

Mohammad Mamun Elahi, Abdullah Al Mosharraf [2022] worked on “Design and Implementation of a Smart Bin using IoT for an Efficient Waste Management System” [7]. The system features three distinct collection boxes, each equipped with sensors and image classification technology, ensuring precise waste categorization. These sensors not only sort the waste but also monitor fill levels, triggering signals for timely collection when the boxes are 70-80% full. Additionally, the smart bins integrate GPS tracking systems for easy location and theft prevention. To boost environmental sustainability, the bins enhancing their eco-friendliness and cost-effectiveness. The development of a functional prototype underscores the efficiency of this intelligent waste management solution. With its advanced technology and seamless integration, this IoT-based smart bin system is poised to transform waste sorting and collection processes, making a significant contribution to a cleaner and more sustainable environment.

Marvin Roy P. Artiaga, Froilan N. Jimeno [2021] focused on “Development of Smart Wastebin Segregation using Image Processing” [8]. The goal is to aid waste segregation by identifying and sorting waste based on three categories: biodegradable, non-biodegradable, and unknown. This intelligent waste bin prototype is designed to follow a user-defined path, enhancing its navigational capabilities. The device, primarily intended for school use but adaptable to other establishments with additional training, undergoes accuracy testing using statistical tools. By efficiently segregating solid waste into designated bins, this system aims to address waste management issues. Its implementation not only mitigates the problem of waste segregation but also contributes to the creation of an eco-friendly society without compromising on health and hygiene standards.

Shaunak Varudandi, Harshwardhan Parmar [2021] proposed a “Smart Waste Management and Segregation System That Uses IoT, ML & Android Application” [9]. The smart waste bins serve as fundamental components of an interconnected waste management ecosystem, utilizing cloud connectivity to monitor and manage waste collection in real-time. This system is complemented by an Android application that empowers authorities with efficient control over bin operations, optimizing waste management workflows. Version 1 of the system addresses current challenges with affordable sensors and instant data analysis capabilities. In Version 2, further advancements are made by integrating camera sensors and image recognition technology, thereby improving waste segregation accuracy and detail. Moreover, citizen participation is encouraged through the app, enabling them to report waste-related concerns, fostering a sense of community engagement and accountability. By seamlessly integrating technology and citizen involvement, this project aims to revolutionize waste management practices, promoting sustainability and efficiency in urban environments.

Muhammed Rijah, Pradeep K. W. [2023] proposed an “Smart Waste Segregation for Home Environment” [10]. The innovative waste management system seamlessly integrates cutting-edge technology to address the pressing issue of efficient waste segregation. By combining an ultrasonic sensor for garbage detection with a camera equipped to capture images of the waste, the system employs a sophisticated Convolutional Neural Network (CNN) like VGG16 to analyze and categorize the waste into distinct types such as paper, plastic, or glass. This automated process not only streamlines waste segregation but also promotes environmental sustainability by encouraging recycling practices and reducing the reliance on intensive contamination management systems. By efficiently sorting waste at the source, the system contributes to a more eco-friendly waste management approach, ultimately reducing landfill waste and conserving resources. Overall, the integration of advanced technology into waste management processes holds significant promise for revolutionizing how we handle and mitigate the impact of waste on the environment.

Features	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	Proposed System
Bin Level Sensing	None	Ultrasonic Sensor	Ultrasonic Sensor	Lid Sensor	Ultrasonic Sensor	Ultrasonic Sensor	Sonar Sensor	Ultrasonic Sensor	Ultrasonic Sensor	Lid Sensor	Ultrasonic Sensor
Weight Sensing	None	None	None	Load sensor	Load sensor	None	None	None	Load sensor	None	Weight Sensor
Ecological footprint	Less	High	High	High	High	Less	Less	Less	High	Less	High
Segregation	Manual	None	None	Manual	None	Manual	Automatic	Manual	Automatic	Automatic	Automatic
Accuracy	Low	High	Low	Low	High	High	Low	Low	High	High	Low

IV. System Architecture

The Fig. 1 shows the system architecture of the smart waste management system.

User: This component represents the user of the smart waste management system. The user can use the mobile app to view the status of the bin, check the type of waste that has been collected, and pay for the garbage collection.

Smart Dustbin: The smart waste bin, a revolutionary waste management solution, employs advanced sensors for real-time monitoring of fill level and weight. Its precision is derived from sophisticated level sensors optimizing waste collection schedules and routes, while weight sensors provide a detailed understanding of waste quantity. The integrated camera system serves critical roles, capturing detailed images for visual waste type verification and contamination detection. Within a connected ecosystem, the bin utilizes IoT technology to transmit real-time data, enabling authorities to enhance operational efficiency and make informed decisions. Through a dedicated mobile app, users receive timely alerts on fill levels, promoting responsible waste disposal. Prioritizing security, the smart waste bin utilizes encrypted communication and access controls, marking a significant transformation in waste management by seamlessly integrating technology to boost sustainability, efficiency, and user engagement.

Testing: Testing of image in the architecture of the smart dustbin you sent me can be defined as the process of evaluating the performance of the machine learning model used to detect the type of waste in the bin. This involves feeding the model a set of test images of different types of waste and measuring the accuracy of its predictions.

Model File: This component contains the machine learning model that is used to detect the type of waste in the bin. The model is trained on a dataset of images of different types of waste, so it can learn to identify different types of waste with a high degree of accuracy.

Waste Segregation and Detection: This component uses the machine learning model to detect the type of waste in the bin. Once the type of waste has been detected, the system can take appropriate action, such as sorting the waste into different bins or sending the waste to the appropriate recycling facility.

Ultrasonic Sensor: This sensor is used to detect the level of waste in the bin. The sensor sends out ultrasonic waves and measures the time it takes for the waves to return to the sensor. The distance to the waste is calculated based on the time delay.

Check Waste Level: This component checks the level of waste in the bin. If the waste level reaches a certain threshold value, the system sends an alert message to the authorities concerned.

Weight Sensing: Weight sensing in a smart waste management system involves monitoring the weight of waste within a bin. When the weight reaches a predetermined threshold, typically set to indicate a significant fill level, the system triggers an alert message. This alert is sent to the relevant authorities, notifying them that the bin needs attention or waste collection. This proactive notification system helps ensure timely waste management interventions, optimizing collection routes and maintaining overall system efficiency.

Mobile App and Alert: This component updates the mobile app with the latest information about the bin, such as the waste level, the type of waste that has been collected, and the status of the garbage collection. This component sends an alert message to the authorities concerned when the waste level in the bin reaches a certain threshold value.

Admin: This component represents the administrator of the smart waste management system. The administrator can use a web portal to view the status of all the bins in the system, and to manage the garbage collection process.

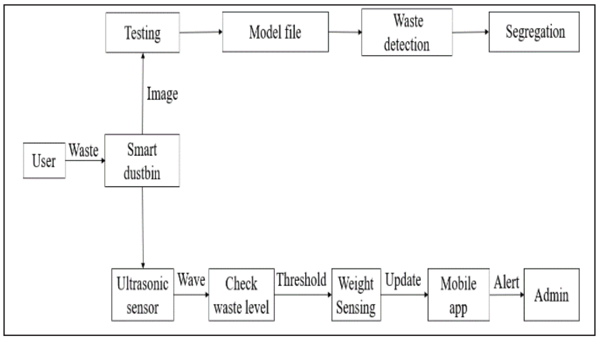


Fig. 1: System Architecture

V. Implementation

A. Sensor Integration

In the implementation phase of the smart waste management system, sensor integration plays a crucial role in accurately monitoring waste levels and weight within the trash bins. The selection and integration of appropriate sensors are essential tasks, requiring careful consideration of factors such as functionality, accuracy, and reliability. For waste level monitoring, ultrasonic sensors are utilized due to their ability to measure distances accurately. These sensors emit high-frequency sound waves and measure the time taken for the waves to bounce back after hitting the surface of the waste pile. This enables precise determination of the waste level within the bin. Additionally, weight sensors are employed to measure the weight of the accumulated waste. These sensors provide real-time data on the weight of the waste, allowing for more accurate monitoring and management of waste accumulation. By combining ultrasonic sensors for threshold level detection and weight sensors for weight sensing, the smart waste management system ensures comprehensive and precise monitoring of waste levels in the bins. The Fig. 2 shows the integration of sensors enables the system to trigger alerts to relevant authorities when waste levels reach predefined thresholds, facilitating timely intervention and efficient waste management strategies.

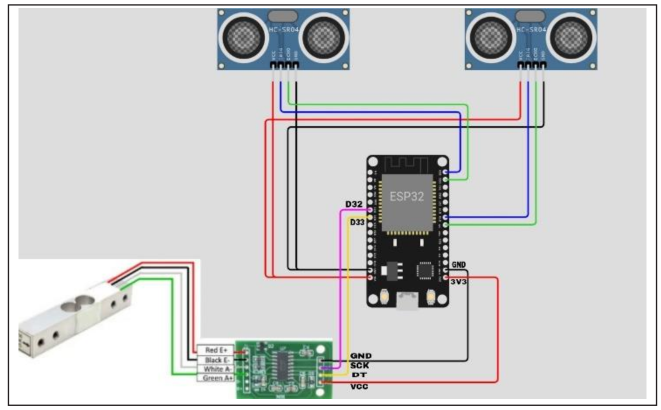


Fig. 2: Circuit Diagram

B. Hardware Development

In the hardware development phase of the smart waste management system, meticulous attention is given to designing and constructing the physical infrastructure of the smart trash bins. These bins are engineered to accommodate various components essential for efficient waste monitoring and management. The design includes separate compartments within the bin to facilitate segregation of recyclable and non-recyclable waste materials. A servo motor mechanism is integrated into the bin structure to enable automated segregation based on waste type. This servo motor is strategically positioned to control the movement of a partition within the bin, allowing for the separation of waste into distinct compartments.

Moreover, the bins are equipped with a comprehensive array of sensors to enable accurate monitoring of waste levels and types. At the bottom of each compartment, weight sensors are installed to precisely measure the weight of accumulated waste. These sensors provide real-time data on the amount of waste present in each compartment, facilitating effective waste management practices. Additionally, ultrasonic sensors are positioned at the top of each compartment to monitor waste levels. By emitting high-frequency sound waves and measuring the time taken for the waves to bounce back, these sensors accurately determine the level of waste within the compartments.

Furthermore, the design incorporates a stand where users can deposit waste into the bins. To enhance the waste segregation process, a camera system is integrated into the stand. This camera system is equipped with image recognition technology, allowing it to identify whether deposited waste is recyclable or non-recyclable plastic. Upon detection, the camera communicates with the servo motor to initiate the rotation of the handle, thereby directing the waste into the appropriate compartment based on its recyclability.

Overall, the hardware development phase focuses on creating a robust and functional infrastructure for the smart trash bins, integrating sensors, servo motors, and image recognition technology to enable efficient waste monitoring, segregation, and management.

C. Software Implementation

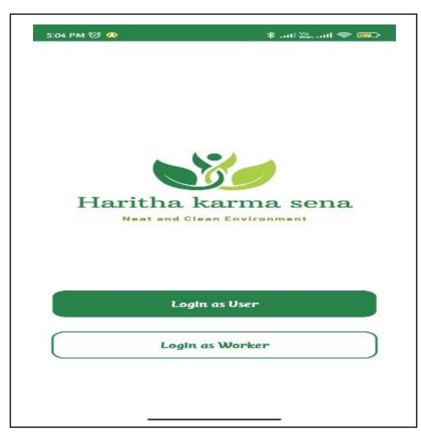
In the software development phase, the focus lies on creating a robust software framework for the smart waste management system, encompassing both the mobile application and the administrative control platform. The mobile application is designed to cater to the needs of both users and workers, providing them with a seamless and intuitive interface. Users and workers can log in using their registered email and password, ensuring secure access to the app's functionalities.

The mobile application is divided into distinct user interfaces for users and workers. For users, the app offers features such as waste collection scheduling, plastic waste segregation options, and payment processing capabilities. Users can conveniently pay their waste disposal bills through the app, streamlining the payment process and enhancing user experience. Additionally, users receive notifications when the bins are full, prompting them to request waste collection. Once the waste is collected by the assigned worker, the app automatically updates the status of the bin to empty, ensuring accurate tracking of waste collection activities.

On the worker side, the app provides functionalities for efficient waste collection management. Workers have access to a map feature that displays the location of the bins, allowing them to navigate to the designated collection points easily. This feature enhances operational efficiency by optimizing route planning and reducing travel time between collection points.

In addition to the mobile application, the administrative control platform is accessible through a website. This platform enables administrators to oversee and manage various aspects of the system, including worker assignments, user accounts, and financial transactions. Administrators have control over worker activities and can monitor the status of waste collection operations in real-time. Moreover, the administrative platform facilitates seamless integration with users' bank accounts, enabling secure and efficient payment processing.

Overall, the software development phase focuses on creating a comprehensive and user-friendly software ecosystem that enhances waste management efficiency, improves user experience, and facilitates seamless coordination between users, workers, and administrators.



D. Connectivity and Communication

In the Connectivity and Communication aspect of the smart waste management system, the focus is on establishing reliable and efficient communication channels for seamless transmission of sensor data to the designated mobile application. This ensures that relevant stakeholders, including users, waste management authorities, and administrators, receive timely updates and alerts regarding waste levels and management activities. Leveraging various connectivity technologies, such as Wi-Fi, Bluetooth, or cellular networks, the system enables continuous monitoring and real-time tracking of waste accumulation within the bins. This facilitates proactive intervention and efficient waste management strategies, as authorities are promptly alerted when waste levels reach predefined thresholds. By establishing robust connectivity and communication protocols, the smart waste management system enhances operational efficiency, improves decision-making processes, and contributes to the creation of a more sustainable waste management ecosystem.

E. Data Management and Analytics

In the Data Management and Analytics component of the smart waste management system, the focus is on efficiently handling and analyzing the vast amount of sensor data generated by the bins. This involves implementing robust data management techniques to store, process, and analyze the data in a timely and effective manner. By leveraging advanced analytics algorithms, the system can derive valuable insights from the collected data, such as waste accumulation patterns, usage trends, and operational efficiency metrics. These insights enable waste management authorities and administrators to make informed decisions and optimize waste management strategies. Additionally, the system facilitates proactive intervention by triggering alerts to relevant authorities when waste levels exceed predefined thresholds. By effectively managing and analyzing sensor data, the smart waste management system enhances operational efficiency, improves decision-making processes, and contributes to the development of a more sustainable waste management ecosystem.

F. Monitoring and Maintenance

In the Monitoring and Maintenance aspect of the smart waste management system, continuous oversight and upkeep are crucial to ensure its smooth operation and longevity. This involves implementing robust monitoring mechanisms to track the performance of the system components, including sensors, hardware infrastructure, and software applications. Regular maintenance activities such as sensor calibration, software updates, and hardware inspections are essential to address any potential issues and ensure optimal functionality. Additionally, proactive monitoring allows for timely detection of anomalies or malfunctions, enabling prompt troubleshooting and preventive maintenance actions. By establishing effective monitoring and maintenance protocols, the smart waste management system can sustain its performance, reliability, and efficiency over time, thereby contributing to the overall success of waste management initiatives and supporting the development of a more sustainable ecosystem.

VI. Future Scope

The project's future scope is promising, addressing the growing challenge of waste management with innovative AIoT solutions. Moving forward, the system could be further enhanced by integrating advanced machine learning algorithms to optimize waste collection routes and schedules based on historical data and real-time sensor inputs.

Additionally, incorporating blockchain technology could enhance transparency and accountability in waste management transactions, ensuring fair compensation for waste disposal services and incentivizing proper waste disposal practices. Furthermore, expanding the system's capabilities to include automated sorting and recycling processes could significantly reduce the burden on manual labor and contribute to a more circular economy. Moreover, integrating a garbage compression feature with a compression plate would maximize bin capacity, reducing the frequency of emptying and transportation requirements, thus enhancing operational efficiency and reducing costs. Overall, the project holds great potential for scalability and adaptation to meet evolving waste management needs, paving the way for smarter and more sustainable urban environments.

VII. Conclusion

In conclusion, the integration of Internet of Things (IoT) technology into waste management through the introduction of smart waste bins, coupled with a user-friendly mobile app and web-based platform, presents a promising solution to the challenges faced by initiatives like Haritha Karma Sena. By automating the waste collection process and providing real-time data monitoring, this innovative approach not only addresses the issue of irregular waste collection but also significantly improves efficiency, accuracy, and accountability in managing household waste. The implementation of smart waste bins equipped with sensors allows for precise monitoring of waste levels, enabling authorities to optimize collection routes and schedules while reducing operational costs. Additionally, the accompanying mobile app and web platform empower users to track their waste disposal habits, schedule pickups, and even make payments for disposal services, fostering a more transparent and efficient waste management ecosystem. Overall, this integration of IoT technology holds immense potential to revolutionize waste management practices, leading to cleaner, greener, and more sustainable communities.

The IoT-enabled smart waste bins offer a proactive system, alerting authorities when bins are nearing capacity, thus preventing overflow and environmental pollution. The web-based platform and mobile app provide a seamless interface for both administrators and users, enabling easy data entry, monitoring, and payment for services. Additionally, the unique ID assigned to each bin allows for precise tracking, ensuring timely actions and enhancing overall responsiveness.

Implementing this advanced waste management system offers communities a powerful tool to make substantial contributions to environmental cleanliness and health. Beyond simply reducing waste and ensuring its proper disposal, this initiative fosters awareness among residents about the importance of responsible waste management. By setting an example of efficient waste handling, the project not only benefits the immediate community but also serves as a model for broader adoption of sustainable practices. As more communities embrace similar initiatives, the cumulative impact can lead to a significant reduction in environmental degradation and the promotion of a healthier planet for future generations. This concerted effort toward sustainable waste management not only improves the quality of life for current residents but also lays the foundation for a greener and more sustainable future for all.

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