International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 12 | Dec - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

EcoBin Connect : Smart Waste Management for Sustainable Cities

Karthik Sri Muchinapalli
B.Tech. student, Dept. of CSE
Institute of Aeronautical Engineering
Hyderabad, India
karthiksrim04@gmail.com

N Nikhil
B.Tech. student, Dept. of CSE
Institute of Aeronautical Engineering
Hyderabad, India
narsingojunikhil11@gmail.com

R Nikhil
B.Tech. student, Dept. of CSE
Institute of Aeronautical Engineering
Hyderabad, India
nikhilrudrarapu210@gmail.com

Dr. Y. Mohana Roopa
Dept. of CSE
Institute of Aeronautical Engineering
Hyderabad, India
ymohanaroopa@iare.ac.in

***Abstract*—The advent of IoT (Internet of Things) has revolutionized smart waste management, making waste collection more efficient and environmentally sustainable. With the integration of smart bins equipped with sensor technology, waste monitoring has become a real-time activity. These sensors provide real time data on bin levels, enabling route optimization for waste collection vehicles. This not only enhances waste segregation but also supports environmental sustainability by reducing unnecessary trips and fuel consumption. Advanced waste analytics and predictive maintenance further contribute to efficient recycling management and resource efficiency. By leveraging data-driven decision making, IoT-based smart waste management solutions offer sustainable waste solutions, promoting waste reduction and a smarter infrastructure for modern urban environments.**

***Keywords—IOT (Internet of Things), Sensor Technology, Waste Segregation, Bin Level Monitoring, Resource Efficiency, Predictive Maintenance*.**

I. INTRODUCTION

Managing waste efficiently is a critical challenge for large cities worldwide, as population growth and urbanization place increasing pressure on traditional waste management systems. These systems often rely on manual monitoring and fixed schedules for garbage collection, leading to inefficiencies such as overflowing dumpsters in some areas and underutilized ones in others. This disorganized approach not only strains resources but also contributes to environmental and health concerns. To address these issues, an innovative waste management solution utilizing IoT (Internet of Things) technology is proposed. This system introduces smart dumpsters that separate wet and dry waste and are equipped with sensors to monitor fill levels in real-time. By providing timely alerts and enabling data-driven collection schedules, this IoT-based approach promises to revolutionize urban waste management, making it more efficient, responsive, and sustainable.

II. EXISTING SYSTEM

Manual waste management methods, where workers are tasked with emptying dumpsters on a regular basis, face numerous challenges that significantly hinder their effectiveness. One of the primary issues is the lack of a systematic method, which leads to inefficiencies and inconsistencies in waste collection. Without a structured approach, there is considerable uncertainty regarding the state of cleanliness in various areas, making it difficult to ensure that all locations are adequately serviced. Furthermore, the absence of real-time data exacerbates this problem, as workers often lack awareness about which specific locations require immediate attention. This lack of awareness means that some areas may be neglected, while others are serviced unnecessarily, leading to wasted resources and efforts. The consequence of this disorganization is an extremely low efficacy in cleaning cities, as the manual methods do not adapt to the dynamic needs of urban environments[18]. The inefficiency of these traditional practices not only impacts the cleanliness and hygiene of cities but also has broader implications for environmental sustainability. Without an optimized waste management system, cities struggle to keep up with the growing volume of waste, leading to increased pollution and health hazards. The reliance on manual labor and outdated methods underscores the urgent need for innovation in waste management.

III. LITERATURE REVIEW

India's urban areas produce a lot of waste annually. Managing all that waste has numerous obstacles, making it a major problem for our nation. Conventional trash collection methods are not particularly effective. You see, the authorities are notified only when the waste bin is full. This frequently results in garbage piling up everywhere. We seriously need enhanced methods to collect and dispose of trash if we are to maintain India clean and green. Here's a clever waste management solution utilizing an Internet of Things-based trash can! This trash can can monitor its level and assist in collecting waste more effectively. Two ultrasonic sensors are used in the system, and they are managed by a Node MCU. A single sensor measures the bin's fill level. The other sensor is used to detect when someone is approaching to dump their waste. The lid opens and closes automatically. For this reason, the lid has a servo motor attached to it, which facilitates smooth up and down motion. When the trash can fills up, the appropriate authorities are notified so they can take the necessary steps. Furthermore, we can keep an eye on all of this data via the Blynk app.This whole system is reliable, budget-friendly, and super easy to set up! It's a step towards a cleaner, smarter India.

To create cities that are greener, safer, & more efficient, the of Things (IoT) can play a crucial role. Connecting, vehicles, & infrastructure throughout a city lead to improvements in safety and the overall quality of life. In cities, the best technological solutions emerge when various stakeholders collaborate effectively. System integrators, network operators, and technology providers must partner with governments to enable these smart solutions. However, there's a challenge: constructing such solutions requires an open platform for communication that adheres to standards and can be utilized continuously. We present a waste collection management solution that aims to enhance intelligence in waste bins through an IoT prototype equipped with sensors. This technology can read, gather, & transmit a vast amount of data via the Internet. When this data is analyzed within a spatio-temporal context and processed by optimized algorithms, it can help manage waste collection systems dynamically. Simulations have been conducted in several scenarios to explore the benefits of this system in comparison to traditional waste management methods. We attempted to replicate these scenarios using Open Data from Pune, India. This effort highlights the opportunities that such initiatives create for multiple parties to innovate & contribute toward developing intelligent waste management solutions..

The Internet of Things (IoT) helps create connections & ensures accountability allowing for seamless data transfer across many different systems. Intelligent cities use a variety of sensors, devices, & IoT solutions to promote a more pleasant living environment. One major focus is on establishing an eco-friendly, effective, and supportive waste management system. Yet, waste management often gets overlooked in developing nations, leading to an urgent need for improvement.This paper aims to design an IoT-based intelligent waste management system specifically for developing countries, such as Bangladesh. The goal is to enhance the collection, disposal, & transportation of waste while using minimal resources. We present an efficient architecture for this waste management system that guarantees proper waste storage over a limited timeframe.The proposed device includes several key components: the Arduino Mega microcontroller, USR-C215 IoT Wi-Fi module, GPS & GSM modules, along with ultrasonic and infrared sensors. When someone throws waste into the bin and it reaches its capacity, an alarm will go off to notify collectors that the trash can is full. This feature helps save time and prevents overflow.Additionally, the main focus of this paper is to develop a garbage management system that is not only highly effective but also cost-efficient. It will streamline waste collection in the easiest way possible.

IV. PROPOSED SYSTEM

At present, the biggest problem facing large cities worldwide is how to manage waste management without causing the city to become unclean. In today's garbage management systems, a huge number of workers are assigned to periodically monitor a specific number of dumpsters on a daily basis. This results in a very disorganized and inefficient system where some dumpsters may not even be halfway filled and some dumpers will be overflowing. It is hard to pinpoint which area need emergency care because of variations in the city's population density or other random factors. An efficient solution to the waste management problem is presented here in the form of a waste management system that includes the ability to separate wet and dry waste into two separate containers and embeds each dumpster with a monitoring system that will alert the corresponding personnel if the dumpster is full. To develop the IoT system, the ESP32 module is used which consumes less power and operates more efficiently when compared with Arduino.

An effective solution to the waste management problem is introduced through a system designed to separate wet and dry waste into two distinct containers, each equipped with a monitoring system that notifies personnel when the dumpster is full. This IoT system is developed using the ESP32 module, which is more power-efficient and operates more effectively compared to the Arduino used in existing systems. Additionally, the ESP32 is more cost-effective, making it a superior choice for this application. The primary advantages of this system include its ability to efficiently separate waste types, ensuring proper disposal and recycling processes. The integration of a monitoring system enhances operational efficiency by providing real-time alerts when dumpsters need to be emptied, reducing the chances of overflow and associated hygiene issues. The use of the ESP32 module further enhances the system's efficiency due to its lower power consumption and superior performance. Moreover, its cost-effectiveness makes the system more economically viable, promoting broader adoption and implementation.

V. METHODOLOGY

The approach taken for this smart waste management system, which uses IoT technology, aims to make monitoring and managing waste levels in bins easier. It combines sensors, micro, & cloud computing. Ultrasonic sensors are put on both wet and dry bins to measure the distance from the sensor to the top of the waste all the time. This measurement is very important for checking how full the bins are.

The main part of the system is the ESP microcontroller. It acts as the brain, getting data from the ultrasonic sensors and talking to the internet through WiFi. The ultrasonic sensors send out sound waves. These waves bounce off the waste surface and return to the sensor. The microcontroller times how long it takes for the sound waves to come back and works out how far it is to the waste level. From these readings, it figures out how full each bin is, turning that into a percentage. These percentages get shown right away on an LCD screen connected to the microcontroller. This screen gives instant feedback on waste levels, so users can quickly see how full each bin is. When a bin hits 100% capacity—meaning it’s full—the system sends out a message that says "The bin is full" on the LCD. This feature helps users know immediately when a bin needs emptying, which keeps things clean. To make things even easier, there’s also a servo motor in place. This motor opens & closes the bin lids automatically. It makes throwing away trash simpler and cuts down on touching the lids manually.

Besides local tracking, this system works with ThingSpeak, which is a cloud platform. This link allows all collected data to be sent up to the cloud, where it can be checked from afar for real-time monitoring & analysis. Authorities that manage waste can keep tabs on bin status from wherever they are, helping them plan collection

schedules better and step in when needed. All in all, this system runs independently while updating waste levels & alerts in real-time. By minimizing manual work & providing effective monitoring, this smart waste management system promotes a cleaner way of handling trash while boosting both ease of use & efficiency in operations.

VI. IMPLEMENTATION

The smart waste management project based on IoT is all about using technology in a planned way. It aims to build an automated system. This system helps in monitoring and managing how full waste bins are. First, there's a need to select and set up hardware parts like ultrasonic sensors, an ESP32 microcontroller, an LCD display, and a servo motor. To start, ultrasonic sensors get attached to both wet & dry waste bins. These sensors measure how far waste is from them. They send out ultrasonic pulses. Then they measure how long it takes for those pulses to bounce back. This process gives accurate distance readings that help figure out the fill levels of the bins.

The ESP32 microcontroller does the number crunching. It collects data from the sensors, calculates the percentage of waste inside, & shares info with the cloud service. The ESP32 handles several tasks at once: reading sensor data, calculating fill levels, updating the LCD display, & communicating with ThingSpeak, which is a cloud-based IoT platform. Since it connects to WiFi, it can send out bin status updates in real time. Waste management authorities can then check on bins from anywhere. The LCD display acts like a monitor for the users. It shows current fill levels for wet & dry bins with clear percentages. This way it's easy for users to see what's going on. If a bin fills up completely, an alert pops up saying, "The bin is full," on the screen. This alert helps prevent overflow and makes sure that waste collection happens on time.

Adding a servo motor makes things easier for users. This motor opens and closes the lids of the bins automatically. When a bin is full or needs trash added, it activates to lift the lid for easy disposal. With this feature, there's less need for people to get involved manually, which improves how users experience the system. In the last step of putting everything together, all components must work well together. The ESP32 microcontroller manages data from sensors while controlling the servo motor and updating both the LCD display and cloud platform too. The LCD display's visibility and clarity are evaluated to ensure that the waste levels and alert messages are easily readable under various lighting conditions. The display's response time is also checked to verify that it updates in real-time as expected.

The ThingSpeak platform is set up to receive data from ESP32, allowing for real-time monitoring & analysis. This smart waste management project mixes ultrasonic sensing tech, programming of microcontrollers, cloud integration, and automation to provide an easy-to-use waste management solution. This system not only automates tracking processes but also sends real-time alerts & data. This leads to better waste management overall plus improved cleanliness and efficiency in operations. By providing real-time data, automated alerts, and convenient waste disposal features, the system enhances waste management practices, contributing to a cleaner and more organized environment.

VII. FIGURES

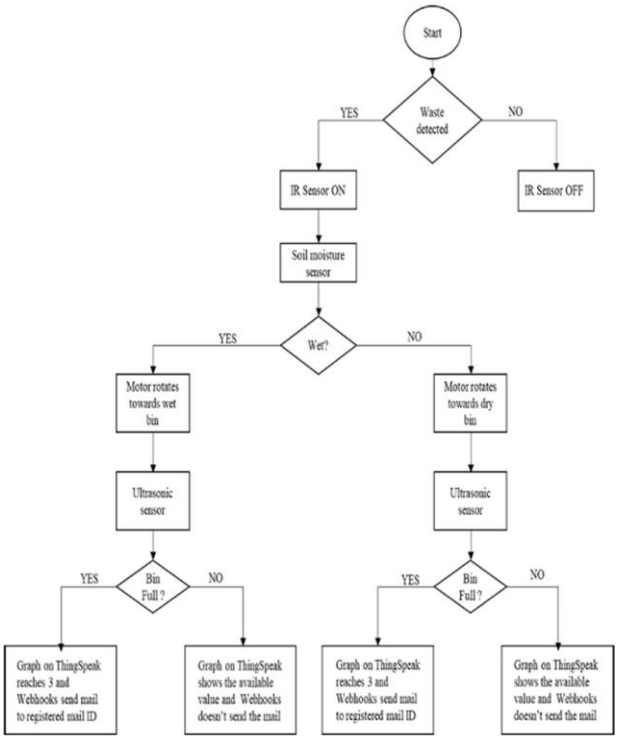

Fig 7.1 Process flow diagram

Fig 7.2 ESP32 Wi-Fi Module

Fig 7.3 Servo Motor

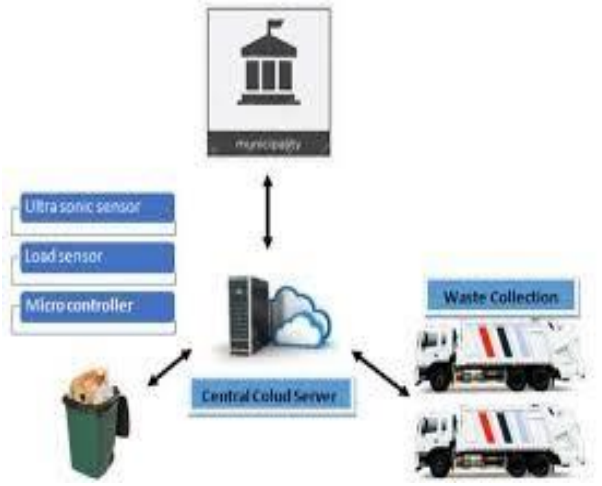

Fig 7.4 System Architecture

VIII. RESULT AND DISCUSSION

The implementation of the Smart waste management system using IoT led to several significant improvements. By utilizing IR sensors to monitor bin fill levels, the system optimized waste collection routes, prioritizing full bins and reducing unnecessary trips. This not only lowered fuel consumption but also decreased operational costs. The integration of moisture sensors allowed for effective differentiation between organic and non-organic waste, enhancing the segregation process and improving recycling rates. LCD displays mounted on the bins provided real-time status updates and user instructions, facilitating better user interaction and compliance. The automated lid mechanisms controlled by servo motors ensured hygienic and efficient waste disposal, minimizing human contact and improving overall sanitation. The system's real-time data transmission via ESP32 to a central server enabled efficient monitoring and predictive maintenance, preventing overflow and ensuring timely interventions.

In this project, we created a smart waste management system based on IoT technology. This system keeps track of how full wet and dry waste bins are by using ultrasonic sensors. It offers real-time data about the bins' status and sends this info to a cloud platform called ThingSpeak for easy remote monitoring. You can also see the waste levels displayed on an LCD screen. Plus, if a bin is, an alert message pops up.The system effectively detects the waste levels in the bins. The display updates to show the fill percentage. Bins are marked as empty, half-full, three-quarters full, or full, based on the measurements from the sensors. When a bin is at 100% capacity, it shows an alert message—"The bin is full"—indicating that it needs to be emptied.This system works automatically, without any help from people, & can tell the difference between wet & dry waste. Thanks to WiFi integration, data can be sent to the cloud for remote access. This makes it easier for waste management teams to schedule bin collections efficiently.

A servo motor in the project allows for automatic opening of bins, which makes disposing of trash simpler. Overall, this system demonstrates how IoT can be applied in waste management. It helps reduce manual work and boost efficiency. Ultimately, this leads to cleaner environments. The real-time data ensures that action can be taken quickly to prevent overflows and keep public areas hygienic.

Fig 8.1 Smart bin equipped with LCD display and sensors

Fig 8.2 Real-time data dashboard for monitoring bin status

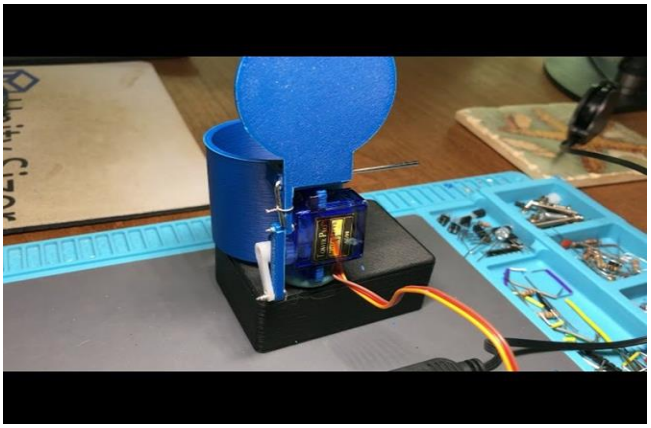

Fig 8.3 Servo motor attached to bin lid for automated opening and closing

IX. CONCLUSION

The Smart waste management system using IoT uses ESP32 microcontrollers, servo motors, and LCD displays has significantly enhanced the efficiency, effectiveness, and sustainability of urban waste management. The ESP32 microcontroller's processing power and connectivity enable real-time data collection from IR and moisture sensors, optimizing waste collection routes by prioritizing full bins and reducing unnecessary trips. This leads to lower fuel consumption, operational costs, and carbon emissions, contributing to environmental sustainability.

Servo motors automate bin lids, ensuring hygienic waste handling by minimizing human contact, preventing overflow, and maintaining cleaner urban spaces. LCD displays provide real-time status updates and disposal instructions, improving user compliance and waste segregation at the source, which enhances recycling rates and reduces contamination.

The LCD displays installed on the bins play a vital role in enhancing user interaction and compliance. These displays provide real-time information on the status of the bins, such as fill levels and types of waste, along with instructions for proper waste disposal. This immediate feedback helps users dispose of waste correctly, improving segregation at the source and reducing contamination of recyclable materials. Clear instructions and status updates also facilitate better engagement from the public, fostering a sense of responsibility and participation in waste management efforts. In conclusion, the Smart waste management system using IoT utilizing ESP32, servo motors, and LCD displays offers a comprehensive solution to modern waste management challenges.

REFERENCES

[1] Parkash, Prabu V "IoT Based Waste Management for Smart City" International Journal of Innovative Research in Computer and Communication Engineering, Vol. 4, Issue 2, DOI: 10.15680/IJIRCCE.2016. 0402029, February 2016.

[2] Evaluation on the Performance of Urban Domestic Sewage Treatment Plants in China - 2011 Dongmei Han; Guojun Song

[3] Teemu Nuortioa, Jari Kyto¨jokib, Harri Niskaa, Olli Bra¨ysyb "Improved route planning and scheduling of waste collection and transport", Expert Systems with Applications 30 (2006) 223– 232, Elsevier

[4] M. Arebey, M. Hannan, H. Basri, and H. Abdullah, "Solid waste monitoring and management using RFID, GIS and GSM", The IEEE Student Conference on Research and Development (SCOReD), 16-18 November 2009, UPM Serdang, Malaysia, 2009

[5] M. Hannan, M. Arebey, R. A. Begum, and H. Basri, "Radio Frequency Identification (RFID) and communication technologies for solid waste bin and truck monitoring system", Waste Management, Vol. 31, pp. 2406-2413, 2011.

[6] S. Longhi, D. Marzioni, E. Alidori, G. Di Buo, M. Prist, M. Grisostomi, et al., "Solid Waste Management Architecture Using Wireless Sensor Network Technology", The 5th International Conference on New Technologies, Mobility and Security (NTMS), 7-10 May 2012, Istanbul, pp. 1-5, 2012. 147

[7] IOT Based Smart Garbage alert system using Arduino UNO Date and journal: 2016 IEEE Region 10 Conference (TENCON) Author: Dr.N.SATHISH KUMAR, B.VIJAYALAKSHMI, R. JENIFER PRARTHANA, A .SHANKAR (S.R.M., Coimbatore, INDIA)

[8] Solid waste management based upon IoT for Smart city Date and Journal: ICICCS 2017 Author: Krishna Nirde, Prashant S. Mulay, UttamM.Chaskar (C.O.E. Pune).

[9] SVASTHA: An effective solid waste management system in Android OS Date and journal: 2013 by IEEE Global humanitarian technology Author: Issac and akshai

[10] SMART DUSTBIN MANAGEMENT SYSTEM Date and journal: 7 may 2018 (IJESRT) Author: Swati Sharma and sarabjeet Singh

[11] C. K. M. Lee and T. Wu, "Design and development waste management system in Hong Kong," 2014 IEEE International Conference on Industrial Engineering and Engineering Management, Bandar Sunway, 2014, pp. 798-802.

[12] S. V. Kumar, T. S. Kumaran, A. K. Kumar and M. Mathapati, "Smart garbage monitoring and clearance system using internet of things," 2017 IEEE International Conference on Smart Technologies and Management for Computing, Communication, Controls, Energy and Materials (ICSTM), Chennai, 2017, pp. 184-189.

[13] S. Balamurugan, A. Ajithx, S. Ratnakaran, S. Balaji and R. Marimuthu, "Design of smart waste management system," 2017 International conference on Microelectronic Devices, Circuits and Systems (ICMDCS), Vellore, 2017, pp. 1-4.

[14] S. Thakker and R. Narayanamoorthi, "Smart and wireless waste management," 2015 International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS), Coimbatore, 2015, pp. 1- 4.

[15] Omara, Ahmed &Gulen, Damla&Kantarci, Burak&Oktug, Sema "Trajectory Assisted Municipal Agent Mobility: A Sensor-Driven Smart Waste Management System" Journal of Sensor and Actuator Networks. 7. 29. 10.3390/jsan7030029.

[16] B. Chowdhury and M. U. Chowdhury, "RFID-based real-time smart waste management system," 2007 Australasian Telecommunication Networks and Applications Conference, Christchurch, 2007, pp. 175-180.

[17] S. Longhi et al., "Solid Waste Management Architecture Using Wireless Sensor Network Technology," 2012 5th International Conference on New Technologies, Mobility and Security (NTMS), Istanbul, 2012, pp. 1-5.

[18] G. K. Shyam, S. S. Manvi and P. Bharti, "Smart waste management using Internet-of-Things (IoT)," 2017 2nd International Conference on Computing and Communications Technologies (ICCCT), Chennai, 2017, pp. 199-203.

[19] A. S. Bharadwaj, R. Rego and A. Chowdhury, "IoT based solid waste management system: A conceptual approach with an architectural solution as a smart city application," 2016 IEEE Annual India Conference (INDICON), Bangalore, 2016, pp. 1-6.

[20] A. S. Wijaya, Z. Zainuddin and M. Niswar, "Design a smart waste bin for smart waste management," 2017 5th International Conference on Instrumentation, Control, and Automation (ICA), Yogyakarta, 2017, pp. 62- 66.

[21] Security Challenges in the Integration of IoT with WSN for Smart Grid ApplicationsViswanathan, A., Sai Shibu N. B., Sethuraman Rao, & Dr. Maneesha V. Ramesh In 2017 IEEE International Conference on Computational Intelligence and Computing Research(ICCIC) (2017).

[22] Goris, L. M.,Harish, M. T., & Rao R. Bhavani "A system design for solid waste management: A case study of an implementation in Kerala" TENSYMP 2017 - IEEE International Symposium on Technologies for Smart Cities(2017)

[23] Kumar RP, Smys S, "A novel report on architecture, protocols and applications in Internet of Things (IoT)" 2018 2nd International Conference on Inventive Systems and control (ICISC) 2018 Jan 19 (pp.1156-1161). IEEE.