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Review Article

A Comprehensive Review of How the Smart Waste Management System Works

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Abstract
Managing and gathering waste in an inventive way is called smart waste management. Smart trash management, which is based on Internet of Things technology, offers information on waste generating patterns and behaviors. This enables waste collectors, towns, and municipalities to streamline their waste operations, increase their sustainability, and make more astute business judgments. Having a healthy environment and smart health services available is one of a smart city's key characteristics. This study explores the functioning of smart waste management systems.

Keywords: *Wireless Sensor Networks, Waste Bin, Buildings, Cities, Clean, Internet of Things.*

I. INTRODUCTION
In cities especially, waste management is a huge challenge for many sides of society. There is a direct correlation between changes in lifestyle and population growth and the daily increase in rubbish creation. This increase in trash output contributes to environmental contamination and a number of other health problems. The accumulation of waste, particularly from families, is caused by a number of factors, one of which is the absence of direct control by garbage collectors. Due to the regular timetable of the garbage collection process, there may be instances where collectors show up even when the bins are not filled or when they do not show up when the bins are full. This disparity results from a lack of knowledge regarding which bins need to be attended to right away. Effective waste collection management is vital to protect public health and preserve a clean environment. Ultrasonic technology [1]–[3], the Internet of Things (IoT) [4]–[9], Telegram [10], [11], SMS [12], and the use of Arduino [13]–[15] are just a few of the many studies that investigate waste management with various technologies. However, Arduino can also be applied in robot development [16]–[18] and medical technology [19], fuzzy logic [20], image processing [21], deep learning [22], and GSM modules [23].

II. RELATED WORKS
With the world population growing, waste management is becoming a bigger problem. We need to find effective solutions to recycle and reuse waste. Since different types of garbage, such as biodegradable and non-biodegradable waste, should be handled differently, waste segregation has become essential to waste management. For this, in particular, effective waste segregation at the fundamental level is needed. Using the Internet of Things (IoT) and GSM, a number of smart waste management solutions targeted at smart cities are also suggested. The current smart bins that use wireless sensor networks (WSN) and the Internet of Things (IoT) rely heavily on two main factors. First, there should be a variety of sensor types because one sensor would not be able to identify certain types of trash. Secondly, there should be connectivity and a console (such as an Arduino Raspberry Pi or Microcontroller) because these depend on programming and the operating system. By merging the Internet of Things (IoT) with artificial intelligence techniques like deep neural network (DNN) systems, these embedded smart bin constraints are addressed. In this research, we have proposed a friendly trash segregator that separates and classes waste objects into biodegradable and nonbiodegradable

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categories using deep learning and the Internet of Things. We present a system that makes use of the Internet of Things (IoT) for connectivity and monitoring through a variety of sensors, and a strong deep learning network for accurate waste classification. After initial training, our suggested method can recognize and separate garbage objects in real-time with an average accuracy of 97.49% without the need for human interaction. Our smart bin aims to promote environmentally safe society by offering efficient bio- and non-bio-waste management [24]. The creation of smart cities is one of the most well-known uses of the Internet of Things (IoT) in current digital age. The internet serves as the backbone connecting smart objects, or devices, in IoT-based smart cities. Using multi-hop communication, the sensed data from the smart objects is sent to the sink for additional processing. The infrastructure and public utilities of the smart cities are improved via the analysis of data, and their services are improved through the application of IoT technology to improve the standard of living for the general public. Waste collection is a major concern for towns trying to achieve a clean environment in IoT-based smart cities. Urban areas are experiencing a population growth, which increases garbage generation. The inadequate procedures for waste collection and segregation are a serious problem in the waste management system. Long before the cleaning procedure is initiated, public trash cans start to overflow, which leads to the growth of bacteria that spreads illness and produces unpleasant odors. This paper proposes an Internet of Things (IoT)-based smart prediction and monitoring system for garbage disposal that uses readily available parts that can be installed to any size bin and measure fill levels in order to address this problem. The suggested device uses an Arduino microcontroller to connect with the weight, infrared, and ultraviolet sensors. A GPS module is used to track the state of the bins at pre-arranged intervals. The proposed system transmits the data using the cluster network to the master module which is connected to the backend via Wi-Fi. As data is collected, an intelligent neural network algorithm namely Long Short-Term Memory (LSTM) is used which will intelligently learn and predict the upcoming wastage from waste generation patterns. In addition, the suggested system makes use of Firebase Cloud Messaging to alert the relevant parties when the trash cans are full and require emptying. Notification messages are sent via the JavaScript Application Programming Interface (API) of Firebase Cloud Messaging (FCM) in web applications running in browsers that allow service work. Therefore, the suggested method benefits society by giving governments the means to enforce more stringent waste disposal laws. The suggested solution also includes extra features like automated bin height calibration, a dynamic web data dashboard, and data collection into a distributed real-time Firebase database [25]. A new technique for linking devices to the Internet is called the Internet of Things (IoT). Maintaining mutual respect on the Internet is the new idea in the IT industry. IoT makes it possible for multiple devices to be connected to one another via the internet. By doing so, the devices are able to exchange and collect data, creating an elegant state. Smart sensors' primary goal is to cooperate with one another without requiring human contact, opening up new possibilities for solutions. Using a smart bin is a necessary step in this process. In smart cities, smart waste management must include smart garbage pickup. Using dustbins is the first step in any waste management system (WMS). To establish a smart waste management system, smart dustbins are required. This study proposes an Internet of Things (IoT) smart trashcan that is integrated with several IoT sensors. The main goal of the suggested approach is to create an intelligent waste management system. To this purpose, Internet of Things devices are used to wirelessly transmit dustbin status information, which can result in a message being shown on the Smart D application. The recipient of this message is informed that the trash can needs to be emptied because it is full. When a human hand is detected, the dustbin lid automatically opens and closes. The dustbin's position is tracked using the Neo-6M sensor, and an Android application is available for customers to keep an eye on the [26]. Building smart cities necessitates the installation of a smart system that tracks the dustbin's location in real time. Currently, Indian municipal corporations are not provided with up-to-date information regarding the location of dustbins. To that end, we are putting in place an Internet of Things (IoT) based system that can notify businesses about the toxicity and overflow of the dustbins. Additionally, a website is being created to oversee the trash data. The dustbin status is updated on the internet, and a message is sent to the mobile phone via the GSM module. Additionally, residents can file complaints about trash management or dustbins on this website. The GSM/GPRS module in the suggested setup is interfaced with sensors via an Arduino microcontroller. The trashcan level and toxicity are measured using ultrasonic sensors and gas sensors, respectively [27]. The generation of solid waste is an issue that is getting worse on a local, regional, and worldwide scale. When solid trash is disposed of properly, it pollutes the air, land, and water in the green environment both locally and globally. Urban society has been producing more garbage as a result of a sharp rise in output or consumption. Due to faster urbanization and economic growth, developing nations deal with this issue more than developed ones. Unsanitary conditions are brought about by the constant flow of trash in every area where individuals travel. It could cause a number of harmful illnesses in anyone in the vicinity. The suggestion is to implement a "smart waste management system" in order to prevent such an occurrence and enhance cleanup. With the use of sensors, the suggested system verifies that the waste in the dustbins is complete. Information is then transmitted via the GSM/GPRS system to the necessary control room. The sensor system and the GSM system connect via a Renesas microprocessor. An Android application has been developed to track waste-related data at various locations of choice. Garbage collection can be done effectively this way [28]. Sending alerts to consumers with a blend of automation and telecommunications technologies is the notification communication method. Using the WeMo’s microprocessor, the smart trash design automates a number of functions, including opening and closing, compacting the waste, and sending out status updates. These alerts are delivered using smartphone Android applications and Firebase web server connectivity. Once testing is completed successfully, the system operates in accordance with the preprogrammed

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specifications. It exhibits an average waste compaction rate of 45%, accomplishes automatic opening and closing within a proximity range of ≤ 10 cm, and notifies users of the garbage status—empty, halfway full, or full [29]. An intelligent smart bin system is installed in buildings to help people manage garbage more easily. Since many are reluctant to recycle, the system makes waste reduction easier and allows users to monitor the bins online. The smart bin's intelligent systems enable it to automatically classify and sort various waste categories. It can also effectively communicate with other devices by utilizing the Internet of Things (IoT) concept. Data is transmitted to the monitoring computer for monitoring, data collection, analysis, and information sending. Additionally, by enabling machine learning to improve the smart bin's performance, robotics is used to enable sorting automation and notify the user from a distance. The suggested system would have made a significant contribution to green technology by lowering the workload for humans, improving waste management effectiveness, encouraging recycling, and creating a cleaner living environment [30].

III. THE ADVANTAGES OR BENEFITS OF CLEVER WASTE MANAGEMENT INCLUDE THE FOLLOWING

1. Using intelligent garbage collection bins and systems with fill level sensors saves time and money. Only the filled bins or containers are visited by smart transport vehicles. Up to 30% less money is spent on operations, maintenance, and infrastructure.
2. Because there are fewer waste collection vehicles on the road, there is less air pollution, which reduces traffic flow and noise. Two-way communication between smart dustbins and service providers has made this feasible.
3. It highlights a healthy atmosphere, maintains our surrounds green and clean, eliminates the stench of waste, and makes cities look better.
4. It also lowers the amount of labor needed to manage the garbage collection process.
5. By optimizing management, resources, and costs through the application of smart waste management techniques, the city becomes a "smart city."
6. It assists the administration in bringing in additional funds by running smart device adverts [31].

IV. CONSEQUENCES OR LIMITATIONS OF AN INTELLIGENT WASTE MANAGEMENT SYSTEM

The following are the negative aspects of intelligent waste management:

1. According to the city's population, the system needs more trash cans for separate garbage collection. Because smart dustbins are more expensive than conventional solutions, this leads to a high initial cost.
2. The dustbins' sensor nodes have a small amount of memory.
3. The system uses wireless technologies with lesser data speeds and shorter ranges, like Wi-Fi and ZigBee. RFID tags in systems that rely on RFID are impacted by nearby metal items, if any.
4. It lowers the need for labor, which causes the unemployment rate for unskilled workers to rise.
5. The individuals using the smart waste management system must receive the training [31].

V. HOW THE SMART WASTE MANAGEMENT SYSTEM WORK

Real-time information on garbage fill levels, collection routes, and bin motions and positions are provided by smart waste management systems. Four components often make to a solution.

1. **Smart Bin Sensors**
   IoT smart sensors are the foundation of smart waste management. Waste container fill levels are tracked using intelligent sensors. The Internet of Things (IoT) network, which links gadgets over the internet, powers them. Every fifteen minutes, smart bin sensors take temperature, fill level, and orientation readings. They then use this information to create 3D topology maps of the bin contents. Intelligent sensors collect information about the patterns of trash generation and transmit it to the cloud. These data are converted into insights and made accessible through the NordSense platform, a smart waste solution.
2. **Smart Waste Management Platform**
   Using analytics, a clever waste management software can convert the information gathered from your bins into useful insights that will enable you to enhance your waste management offerings. You can obtain information on measures like:
   i. Locations prone to overflow
   ii. The number of bins needed to avoid overflowing waste
   iii. The number of collection services that could be saved
   iv. The amount of fuel that could be saved
   v. The driving distance that could be saved

These data insights can assist you in changing the way you manage trash so that it is cleaner, greener, and more intelligent.

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3. **Intelligent Routing**
   Smart routing is also made possible by the data on bin fill levels. Waste collectors can utilize the intelligent waste management software to optimize their collection routes by viewing a digital overview of the bins' fill levels.
   Waste collectors can use the data insights to move to dynamic paths rather than following set collection routes. In this manner, they avoid spending long hours driving prearranged collection routes and picking up every bin regardless of fill level—instead, they only pick up bins that require maintenance.
4. **Container Tracking**
   An integral part of intelligent waste management is having a digital overview of your waste inventory and containers. Because container tracking uses highly accurate data on the position and motions of bins, it gives you transparency over your waste planning procedures.
   You can streamline your inventory management by scheduling container maintenance, monitoring broken bins, and preventing theft by integrating container tracking into your trash solutions [34].

VI. CONCLUSION

For this study, we have examined numerous research publications pertaining to waste management systems, or trash cans. Utilizing the waste management system has a number of benefits, and several technological advancements have occurred [32]. The disadvantages of using the smart waste management system are also covered [33]. There is a thorough discussion of the smart waste management system's operation.

REFERENCES

1. F. R. Maulana, T. A. S. Widyanto, Y. Pratama, and K. Mutijarsa, “Design and Development of Smart Trash Bin Prototype for Municipal Solid Waste Management,” in 2018 International Conference on ICT for Smart Society (ICISS), IEEE, Oct. 2018, pp. 1–6. doi: 10.1109/ICTSS.2018.8550013.
2. D. J. Dasari, V. Satyadeep Velala, B. Ganbaaatar, and N. Kunicina, “Smart Trash Bin Segregation and Identify and Create Alerts on the Level of Waste Present in the Trash Bin,” in 2020 IEEE 8th Workshop on Advances in Information, Electronic and Electrical Engineering (AIEEE), IEEE, Apr. 2021, pp. 1–6. doi: 10.1109/AIEEE51419.2021.9435755.
3. C. Kolhatkar, B. Joshi, P. Choudhari, and D. Bhuva, “Smart E-dustbin,” in 2018 International Conference on Smart City and Emerging Technology (ICSCET), IEEE, Jan. 2018, pp. 1–3. doi: 10.1109/ICSCET.2018.8537245.
4. M. Awawdeh, A. Bashir, T. Faisal, I. Ahmad, and M. K. Shahid, “IoT-based Intelligent Waste Bin,” in 2019 Advances in Science and Engineering Technology International Conferences (ASET), IEEE, Mar. 2019, pp. 1–6. doi: 10.1109/ICASET.2019.8714406.
5. K. F. Haque, R. Zabin, K. Yelamarthi, P. Yanambaka, and A. Abdelgawad, “An IoT Based Efficient Waste Collection System with Smart Bins,” in 2020 IEEE 6th World Forum on Internet of Things (WF-IoT), IEEE, Jun. 2020, pp. 1–5. doi: 10.1109/WFIoT48130.2020.9221251.
6. L. C. Hin, V. A. Hameed, H. Vasudavan, and M. E. Rana, “An Intelligent Smart Bin for Waste Management,” in 2021 IEEE Mysore Sub Section International Conference (MysuruCon), IEEE, Oct. 2021, pp. 227–231. doi: 10.1109/MysuruCon52639.2021.9641618.
7. N. A. Antora, M. A. Rahman, A. Al Mosharraf, M. Ibn Ehsan, M. Alve, and M. M. Elahi, “Design and Implementation of a Smart Bin using IOT for an Efficient Waste Management System,” in 2022 25th International Conference on Computer and Information Technology (ICCIT), IEEE, Dec. 2022, pp. 774–779.
8. M. Bhuvaneswari, K. Tansin, S. T. Ahamed, N. T. Sri Ram, and S. V. Prasath, “Internet of Things based Intelligent Waste Segregation and Management System for Smart Home Application,” in 2022 7th International Conference on Communication and Electronics Systems (ICCES), IEEE, Jun. 2022, pp. 1737–1743. doi: 10.1109/ICCES54183.2022.9835844.
9. S. Lokuliyana, A. Jayakody, G. S. B. Dabarera, R. K. R. Ranaweera, P. G. D. M. Perera, and P. A. D. V. R. Panangala, “Location Based Garbage Management System with IoT for Smart City,” in 2018 13th International Conference on Computer Science & Education (ICCSE), IEEE, Aug. 2018, pp. 1–5. doi: 10.1109/ICCSE.2018.8468682.
10. M. S. Chaudhari, B. Patil, and V. Raut, “IoT based Waste Collection Management System for Smart Cities: An Overview,” in 2019 3rd International Conference on Computing Methodologies and Communication (ICCMC), IEEE, Mar. 2019, pp. 802– 805. doi: 10.1109/ICCMC.2019.8819776.
11. A. Najmurrokhman, E. F. Ramadhan, D. I. Saputra, N. Ismail, and A. Saehu, “Development of Automatic Trash Bin for Sorting Metal and Non-Metallic Wastes Using Proximity Sensors and Notifications via Telegram,” in 2023 9th International Conference on Wireless and Telematics (ICWT), IEEE, Jul. 2023, pp. 1–5. doi: 10.1109/ICWT58823.2023.10335243.
12. N. A. Haqimi and R. T. Kusuma, “Timeline reminder system bot and telegram assistant chatbot for a university student and lecturer,” J. Soft Comput. Explor., vol. 4, no. 4, pp. 186–195, 2023.

@ 2024 | PUBLISHED BY GJR PUBLICATION, INDIA

13. R. Alfiqi and J. P. Sembiring, “Technology for SMS-based assistive device for the visually impaired,” J. Soft Comput. Explor., vol. 4, no. 4, pp. 9–17, 2023, doi: https://doi.org/10.52465/joscex.v4i4.225.
14. A. M. Furqan Durrani, A. U. Rehman, A. Farooq, J. A. Meo, and M. T. Sadiq, “An Automated Waste Control Management System (AWCMS) by Using Arduino,” in 2019 International Conference on Engineering and Emerging Technologies (ICEET), IEEE, Feb. 2019, pp. 1–6. doi: 10.1109/CEET1.2019.8711844.
15. B. S. Sasikanth, L. Naga Yoshita, G. N. Reddy, and M. P.V, “An Efficient & Smart Waste Management System,” in 2021 International Conference on Computational Intelligence and Computing Applications (ICCICA), IEEE, Nov. 2021, pp. 1–6. doi: 10.1109/ICCICA52458.2021.9697316.
16. Y. Gunardi, D. Hanafi, F. Supegina, and Torik, “Mathematics base for mobile robot navigation using mirror Petri net Method,” in nd International Conference on Mechanical, Electronics, Computer, and Industrial Technology, Medan, 2018.
17. Y. Gunardi, A. Adriansyah, and T. Anindhito, “Small smart community: An application of internet of things,” ARPN J. Eng. Appl. Sci., vol. 10, pp. 6341–6347, Jan. 2015.
18. Y. Gunardi, D. Hanafi, F. Supegina, and Torik, “Design of Navigation Mobile Robot Using Mirror Petri Net Method and Radio Frequency Identification,” in 2018 Electrical Power, Electronics, Communications, Controls and Informatics Seminar (EECCIS), IEEE, Oct. 2018, pp. 102–107. doi: 10.1109/EECCIS.2018.8692926.
19. T. M. Kadarina and R. Priambodo, “Preliminary design of Internet of Things (IoT) application for supporting mother and child health program in Indonesia,” in 2017 International Conference on Broadband Communication, Wireless Sensors and Powering (BCWSP), IEEE, Nov. 2017, pp. 1–6. doi: 10.1109/BCWSP.2017.8272576.
20. D. N. Utama, R. Ariyadi, I. Hadi, M. R. Seputra, and Y. Setiawan, “Fuzzy-DSM for Evaluating Waste’s Hazardousness,” in 2019 International Conference on ICT for Smart Society (ICISS), IEEE, Nov. 2019, pp. 1–6. doi: 10.1109/ICISS48059.2019.8969836.
21. T. R. R. Escalona et al., “Design and Fabrication of Solar-Powered Smart Waste Segregation Trash Bin with Image Processing,” in 2022 IEEE 14th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM), IEEE, Dec. 2022, pp. 1–6. doi: 10.1109/HNICEM57413.2022.10109457
22. S. Puig and N. Foukia, “CleverTrash: an IoT system for waste sorting with deep learning,” in 2022 IEEE International Conferences on Internet of Things (iThings) and IEEE Green Computing & Communications (GreenCom) and IEEE Cyber, Physical & Social Computing (CPSCom) and IEEE Smart Data (SmartData) and IEEE Congress on Cybermatics (Cybermatics), IEEE, Aug. 2022, pp. 1–8. doi: 10.1109/iThings-GreenComCPSCom-SmartData-Cybermatics55523.2022.00016.
23. B. Jana, P. Roy, S. Sengupta, S. Porey, and R. Sen, “GSM controlled location specific garbage collecting Smartbin,” in 2019 9th Annual Information Technology, Electromechanical Engineering and Microelectronics Conference (IEMECON), IEEE, Mar. 2019, pp. 211–214. doi: 10.1109/IEMECONX.2019.8877007
24. K. O., Mohammed Aarif's, et al. “Smart bin: Waste segregation system using deep learning-Internet of Things for sustainable smart cities”, Concurrency and Computation Practice and Experience, Vol. 34, No. 9, 2022, http://dx.doi.org/10.1002/cpe.7378.
25. John, J., Varkey, M.S., Podder, R.S. et al., “Smart Prediction and Monitoring of Waste Disposal System Using IoT and Cloud for IoT Based Smart Cities”, Wireless Pers Commun 122, Pp. 243–275, 2022, https://doi.org/10.1007/s11277-021-08897-z
26. S., Singhania, Katal, A., Sharma, R., Agarwal, S., Sharma, V., “Smart D: An IoT-Based Smart Dustbin for Better Waste Management” In: Ramdane-Cherif, A., Singh, T.P., Tomar, R., Choudhury, T., Um, JS. (eds) MachineIntelligence and Data Science Applications. MIDAS Algorithms for Intelligent Systems. Springer, Singapore, 2023, https://doi.org/10.1007/978-981-99-1620-7_21.
27. R. K., Singhvi, et al., "IoT BasedSmart Waste Management System: India prospective," 2019 4th International Conference on Internet of Things: Smart Innovation and Usages (IoT-SIU), Ghaziabad, India, 2019, Pp. 1-6, Doi: 10.1109/IoT-SIU.2019.8777698.
28. A., Jain, et al., "Design and implementation of a smart solid waste monitoring and collection system based on Internet of Things," 2017 8th International Conference on Computing, Communication and Networking Technologies (ICCCNT), Delhi, India, 2017, Pp. 1-5, doi: 10.1109/ICCCNT.2017.8204165.
29. A., Avif, G., Yudhi, H., Abdul, “Design internet of things for smart waste bin management with wemos based and firebase application”, Journal of Soft Computing Exploration, Pp. 276-283, 2024, htttps://shmpublisher.com/index.php/joscex.
30. L. C. Hin, “An Intelligent Smart Bin for Waste Management”, 2021 IEEE Mysore Sub Section International Conference (MysuruCon).
31. https://www.rfwireless-world.com/Terminology/Advantages-and-Disadvantages-of-Smart-Waste-Management System.html.
32. A. S., Munirah, M. DA., Musa, M. A., Ahmad, K. G., Danladi, I. B., Mukhtar, B. A. Muhammad, “The Intelligent Waste Management System” In Global Journal of Research in Engineering & Computer Sciences Vol. 4, Number 2, pp. 140–144, 2024, https://doi.org/10.5281/zenodo.11050825.

@ 2024 | PUBLISHED BY GJR PUBLICATION, INDIA

33. Muhammad A. B, Naima H. A, & Abdulkadir S. B. (2024). Consequences or Limitations of an Intelligent Waste Management System. In Global Journal of Research in Education & Literature (Vol. 4, Number 4, pp. 39–43). https://doi.org/10.5281/zenodo.12743557.
34. https://nordsense.com/the-ultimate-guide-to-smart-waste-management/#:~:text=Smart%20waste%20management%20is%20based,connects%20devices%20through%20the%20internet.

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