Smart Waste Segregation Management System Using Three Sensors

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Abstract: The way waste containers are managed has made waste accumulation and disposal into a major issue for populous cities. The undesired, dangerous, and wasted material left over from regular community events is known as solid garbage. Solid waste management is the control of solid waste generation, storage, collection, transport, treatment, and disposal. Waste containers placed in a wide range of places, including open areas like healing centers, educational institutions, and businesses, have been seen to be overflowing recently. The dustbin overflow creates an unhygienic condition that might transmit disease. Waste is most effectively utilized economically when it is separated. Waste segregation at disposal facilities requires extra manpower and time. With an increasing number of smart cities worldwide, IoT (Internet of Things)-based technological solutions for solid waste management are becoming more essential. These solutions will help in the advancement of a sustainable and clean environment. To ensure the least amount of risk to the environment and public health, it must be taken into consideration when sorting and transporting waste. Economic value of waste can be brought to the limelight by the segregation of waste in proper way. Rag pickers are the traditional way of garbage segregation utilized in India; this approach is time-consuming and harmful to the health of those exposed to the waste. Therefore they propose an idea of Automated Waste Segregator which can be used at household level to segregate the waste in easy way which is also cheap and affordable. In order to fulfill this, smart waste segregation management system using three sensors is presented. In this system, Arduino Uno is used which will monitor the waste segregation and segregates the waste. After the collection of dustbin, the waste segregated as Dry waste, wet waste and Metal waste. In addition, wet waste is composed metal and dry waste is recycled.

Keywords: *Smart Cities, Waste Management, Dustbin, Internet of Things and Arduino Uno.*

I. INTRODUCTION

Internet of things(IoT) is the expansion of web availability into physical gadgets and everyday items are inserted with gadgets, net availability and diverse sorts of equipment,(for example, sensors).These contraptions will convey and connect with others over the web and that they can be remotely observed and controlled [1].

It is a registering thought that depicts the idea of regular physical items being associated with the web and being able to spot themselves to elective gadgets. Usage of a system of sensors and different gadgets through the methods for electronic and other programming so as to get information about that physical gadget. The inexact populace of India is 135 crores. Populace of India is ascending at disturbing rate. At an identical time, India is yet again heading into the most exceedingly terrible time for contamination, a season where the nation's famously awful quality transforms into even a ton of toxicant. Contaminations are key part/pieces of dirtiness that are ordinarily squander materials of various structures [2].

With modernization & movement in our lives contamination has achieved its summit; offering move to a general temperature change and human ailment. Contamination can happen in many sources such as light, water, heat/warm, air and soil. The point and no point sources are the two generous occasion of violation[3]. Point sources can be anything and is remarkably tough to screen, perceive and control, though the non-point sources are just tough to control plastic destruction, total in the earth of designed plastic things to the point where they make issues for characteristic life and their surroundings similarly with respect to human peoples.

Solid waste management (SWM) system is one of the important problems in the present world. The generation of solid waste increases day to day due to many activities of human beings and it causes health and environmental problems. Due to the advancement in technologies and change in life style of the people along with the increase in population and urbanization, large amount of waste is generated and this includes different varieties of post-consumer materials [4]. The organic waste if left unattended will tend to decompose by natural process giving rise to

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odors, hosting and feeding a variety of insects and pests, which in turn, form the carriers of disease creating severe health problems. To solve this problem, an efficient SWM is required. In early days, waste is managed by using four basic means. They are Dumping/Land fill, Burning, Recycling and Waste minimization.

One of the important examples for the waste management system in early days is Maya of Central America had a monthly fixed ritual, in which all people of the village burn their waste. In the modern age SWM has become a public management system, waste is managed through municipal authority [5]. The collection, segregation, decomposition and stabilization of the organic waste by biological action forms the basis of recycling through different natural cycles. Waste consists of number of recyclable materials, for example paper, glass, plastic, rubber, ferrous and non-ferrous metals present that are suitable for recovery and reuse. Proper collection and segregation leads to better options and opportunities for scientific disposal of waste. Recyclables is straightway transported to recycling units and requires segregation of waste which is complicated due to the presence of numerous varieties of materials [6].

The retrospective analysis of development of system of ensuring ecological safety at management of municipal waste shows that all spheres of human activity which are accompanied by usage of energy in various forms (energy of processes, energy of substance, energy of emissions) create living conditions for potential danger of realization of negative events. It can be shown through technogenic incidents, the fires, negative trends or dangerous emissions. The risk was not always the integral component of process of safety in various spheres of safety, including ecological regarding placement of municipal waste[7]. It is become necessary and challenging to manage the solid waste with rapid urbanization and increased population growth. While talking about waste collection and management, the attention can be highly focused towards the common dustbins placed by respective Municipal Corporation at the various area of the each city[8].

The initial approach is to divide the city into several zones using clustering algorithm. The results obtained from the initial step are utilized in further modules. The next part involves the detection of location of dump yard in each zone and determining its maximum capacity [9]. Now after obtaining the suitable dump yard site for each zone, it is desired to build the most optimal route for the waste disposal garbage trucks, thereby gaining economic benefits. The following are the primary challenges to waste recycling: The factors that contribute to MSW management are as follows: (i) insufficient government plan and budget; (ii) low household awareness of the value of recycling one's own waste; (iii) ineffective recycling technology; and (iv) high management costs related to manual waste classification [10].

Solid waste, which is defined as any waste material that is neither in liquid nor gaseous state, can be classified as several categories: agricultural and allied industries, industrial and mining waste, ash from thermal power plants, municipal solid waste, and Industrial Hazardous Wastes (IHW) [11]. Among these five categories, IHW are the most concerned classification thanks to their toxicity and corrosivity characteristic and their significant impacts on public health and the environment. IHW have some distinguishing characteristics, including ignitability, reactivity, corrosivity, infectivity, toxicity, etc. These IHW have to be managed properly, otherwise they may threaten not only ecological environment but also human health, and lead to serious consequence. For example, open dumping of municipal solid waste is a main disposal method for many developing countries, including China. Without strict supervision and management, these wastes will pollute surface water as well as ground water resources, accompanied by the release of toxic contaminants into the air [12]. And it will dirty our cities, more importantly, influence public health such as resulting lead poisoning, carbon bisulphide poisoning, hearing loss, isocyanate poisoning, etc.

Biotreatment of solid waste, literally, is the processes of treating biodegradable waste to produce biogas either aerobically or anaerobically. Compared to aerobic treatment, anaerobic treatment has better performances on dealing with large quantities of microorganisms, reducing the generation of biological sludge and producing methane. Accordingly, anaerobic digestion leads to higher capital and operational costs, and more management problems. The expensive equipment [13], including insulated digester tanks, heating system and lift station pumps, the long payback period of investment and the complexity of operating and maintenance, tend to make the facilities less profitable and more complex.

An embedded network of sensors and services defines the IoT paradigm. These sensors are built in to share data with multiple centralized platforms, track physical conditions, such as the status of garbage bins, and gather a wide range of information [14]. IoT is starting to show promise as a space where devices may communicate and share information to provide consumers innovative services. IoT is being implemented in a number of fields, such as traffic

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management, health care, entity tracking, home environmental monitoring, and smart home technologies that integrate Wi-Fi and sensors. The use of Radio frequency identification (RFID) technology in waste management has been studied by numerous researchers, specifically in the context of real-time knowledge management, solid waste management, and medical waste management [15].

Over the years, many of the researchers used Waste management, classification and Recycling. However most of the techniques focused on waste management but not focused on waste segregation and recycling. Hence to solve these issues, smart waste segregation management system using three sensors is presented. The explanation of the remaining work is arranged is provided below: In section II, the literature survey is presented. The section III designs the smart waste segregation management system using three sensors. In section IV, the results of the analysis is analyzed. The conclusion represents the end of section V.

II. LITERATURE SURVEY

T. J. Sheng et al. [16] demonstrates a smart trash management system based on the internet of things that uses the TensorFlow deep learning model and LoRa (Long Range). Using TensorFlow-based deep learning models and the LoRa communication protocol, this project aims to create a smart waste management system. Tensorflow processes the sensor data in real time classifies detects objects based on LoRa signals. The garbage is divided into multiple compartments in the bin, which are managed by servo motors. The compartments for metal, plastic, paper, and general waste are among them. Using a trained object identification model, TensorFlow handles waste classification and object detection. Using a camera attached to the Raspberry Pi 3 Model B+ as the primary processing unit, an object detection model is trained using waste image information to create a frozen inference graph. To track the garbage's fill level, an ultrasonic sensor is integrated into every waste compartment. An embedded GPS (Global Positioning System) module tracks the bin's location in real time. Data concerning the location, current time, and fill level of the bin are transmitted using the LoRa communication protocol. Personnel identification in waste management can be achieved by the RFID module.

Ahmad S., Imran, Iqbal N., Jamil F. and Kim D. et. al., [17] explains that to make the best possible strategies for managing municipal waste using predictive model optimization. The solid waste dataset from 2017 to 2019 which was produced by several home grids is the topic of the investigation. Together with prediction algorithms, the analysis enables policymakers to create a waste profile matched to a home grid. By considering the quantity and frequency of trash within the grid, the optimization algorithm then suggests the minimal resources required to maintain the area's hygiene standards. Simulated results from different areas are presented, along with a minimum cost recommendation. This supports policymakers to ensure a clean and green environment while also allocating resources effectively. The optimal and economical solution is found by the suggested objective function using the predicted results. These techniques might appear insignificant in developed nations, but in undeveloped ones, they can save a significant amount of money that can be spent in other areas of development.

Imran, Ahmad S. and Kim D. H. et. al., [18] explains that to effectively plan waste management through descriptive and predictive data analysis based on quantum GIS (Geographic Information System). In order to generate in-time waste information, a descriptive data analysis approach is provided in combination with predictive analysis. Using a real garbage dataset from Jeju Island, South Korea, the effectiveness of the suggested approach is evaluated. This Quantum geographic information systems (QGIS) software allows waste containers to be virtualized on their true location on the Jeju map. The predictive analysis models performance results are evaluated using Mean absolute error (MAE), Root mean square error (RMSE), and Mean absolute percentage error (MAPE). Performance data show that predictive analysis models are be depended upon for efficient waste management planning and optimization.

Sonal K Jagtap, Balaji K Vasurkar et. al., [19] explains that smart cities with IoT-based trash management systems work. In order to empower intelligent arrangements, framework integrators, arrange administrators, and innovation providers need to work with governments. However, developing such agreements on a communication platform that is open based on standards can be used is a test. The trash managers may more effectively plan and route the movement of collecting machinery with the support of this technology. Trash cans from overflowing can be prevented. This is in the role of determining the amount of waste in the trash bins and sending the information to a server for processing and storing.

Yuan, Yujun, Tong Li, and Qiang Zhai et. al., [20] presents a comparative case study in China that examines the life cycle evaluation of garbage-classification based municipal solid waste management. Using three proposed garbage classification scenarios in China, the current study aims to thoroughly analyze, through a comparative Life Cycle Impact Assessment (LCIA), the environmental consequences of garbage classification on Municipal solid

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waste management (MSWM) systems. With the use of the Impact Assessment of Chemical Toxics (IMPACT) 2002+ method, the midpoint, endpoint, and single scored life cycle impacts for the MSWM system under consideration can be quantitatively evaluated in this comparative LCIA study. The efficiency and dependability of the LCIA results are evaluated using a Monte Carlo uncertainty analysis. There are significant variations between MSWM systems based on different garbage classification scenarios in the examined midpoint, endpoint, and single scored environmental consequences, based on the LCIA and uncertainty analysis results.

Giulia, Caruso, and Stefano Antonio Gattone et. al., [21] explains that unsupervised classification of mixed data can be used to analyze waste management in developing countries. They are able to differentiate between two different categories due to the analysis. The first has a lower life expectancy among its residents since it is less developed, urbanized, and poor. As a result, it records reduced trash production and CO_2 emissions. It is surprisingly more active in recycling-related awareness initiatives and recycling itself. For every variable within analysis, the second cluster exhibits the opposite tendency since the cluster discrimination between the two groups is clearly established. In conclusion, this type of analysis presents a viable option for researchers and decision-makers to work together on the implementation of waste management plans that are specific to the region.

Wang Z., Teng Y., Jin H. and Chen Z. et. al., [22] explains the Multi-Energy System Coordinated Operation Based Energy Supply Performance Optimal Model for Urban Waste Disposal Capacity. In order to optimize the economic benefits, this work proposes the Multi-energy Waste Disposal System (MEWDS) topology and its optimal model, which is based on coordinated operation of multi-energy systems and waste disposal facilities. As an example, case studies of a Chinese city's garbage stockpile and multi-energy operation data from various waste disposal scenarios are conducted through simulation. The best economic gains and waste reduction can be achieved using the proposed MEWDS optimum model. It can also successfully increase the flexibility of power grid regulation.

Shyam G. K., Manvi S. S. and Bharti P.et. al., [23] explains IoT-based smart waste management. An IoT prototype that contains sensors is used to provide waste bins with intelligence as the basis for a garbage collection management solution. It has the ability to read, gather, and send large amounts of data through the Internet. Waste collection mechanisms can be dynamically managed when such data is processed by intelligent and optimal algorithms within a spatiotemporal environment. The advantages of a system over a conventional system are investigated through simulations for multiple scenarios. Using open data from Pune, India, they attempt to recreate the scenario, highlighting that these types of activities give all parties concerned the opportunity to develop innovative concepts and contribute to the development of smart waste management plans.

Adam M., Okasha M. E., Tawfeeq O. M., Margan M. A. and Nasreldeen B. et. al., [24] IoT-based Waste Management System is described. In this investigation, the utilization of garbage containers is regulated by the application of Internet Of Things (IoT) and Wireless sensor network (WSN). In order to determine the optimal distribution of the containers, this paper describes the use of sensors to monitor the contents of the containers in real time. The results are displayed on the website.

A. Sunday Afolalu, A. Ayodeji Noiki, M. Omolayo Ikumapayi, T. Adebayo Ogundipe, R. Olamilekan Oloyede et. al., [25] explains that smart waste bins are developed for solid waste management. This paper introduces a smart garbage bin that is combined with an Arduino board based on microcontrollers, interfaced with servo motors, LCDs (Liquid Crystal Display), MQ-2 (Metal Oxide semiconductor type gas sensor) sensors, ultrasonic sensors, and GSM (Global System for Mobile Communication modems. The ultrasonic sensor is used to measure the dust bin's height, and the Arduino microcontroller is programmed using Arduino C. When a certain amount of waste has been collected, the microcontroller sends a message to a specified number by activating on the GSM modem. Every time the garbage in the bin exceeds the pre-set amount, the status is shown on the LCD after being shifted to the correct line. Smart trash bins ensure that filled garbage bins are taken out whenever the specified quantity is reached, which are replacing traditional waste bins, support in the efficient management of waste. However, there is a need for further improvement.

III. SMART WASTE SEGREGATION MANAGEMENT SYSTEM USING THREE SENSORS

In this section, smart waste segregation management system using three sensors is presented. Figure 1 displays the presented model's block diagram. The power supply unit which is the initial subsystem, transforms the AC (Analog Current) voltage into a low-level DC (Direct Current) voltage and giving all of the electronic system's DC-powered devices a steady DC-level voltage. A voltage

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regulator, passive parts, and a bridge rectifier make up the power supply circuit.

Moisture Sensor: This is used to evaluate the moisture content of the waste.bin following testing to determine its moisture content. Inductive Proximity Sensor: This type of proximity sensor allows for the detection of object presence even in the absence of physical contact. "Observing the changes in the field or return signal and emitting electromagnetic field or electromagnetic radiation" is the way it finds objects. The metallic waste is identified using an inductive proximity sensor. Metal items can be detected non-contact using inductive proximity sensors.

Their working mechanism is based on the creation of electromagnetic changes in the area of the sensing surface using an oscillator and coil. The oscillation amplitude is dampened when a metallic object (actuator) is present in the operational region.

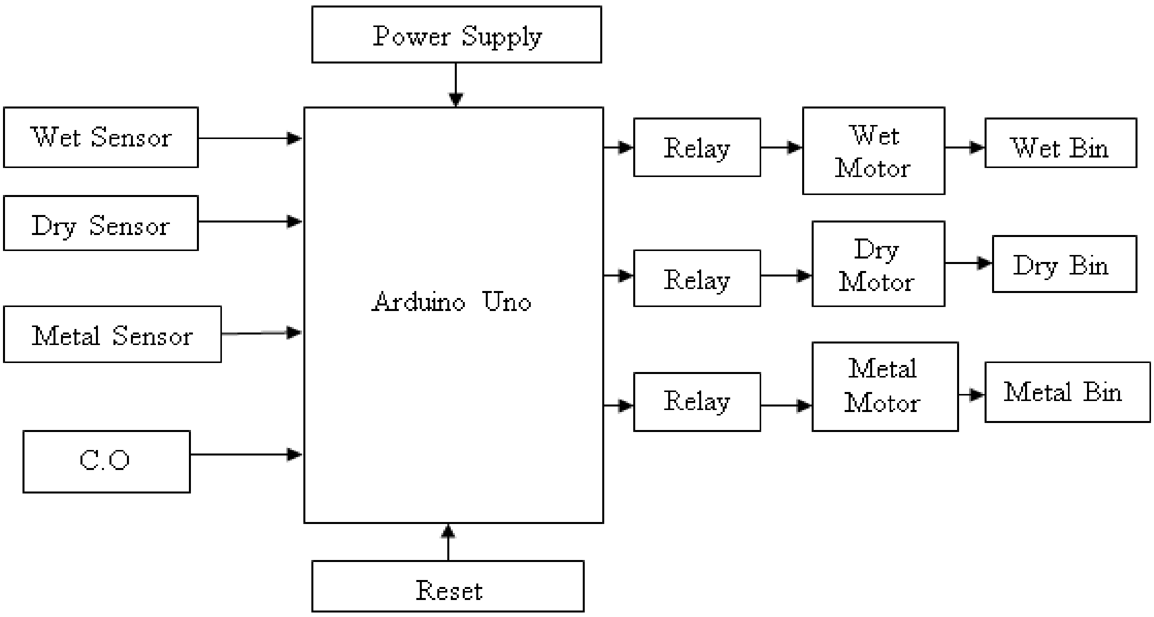

Figure 1: Block Diagram

A threshold circuit that measures the oscillation's increase or fall uses the sensor's output. The actuator's size and form determine the sensor's operating distance, which is directly related to the material field's characteristics. Capacitive Proximity Sensor: Paper and plastic can be differentiated from one another using a capacitive proximity sensor. This sensor is used to detect and count non-metallic objects like paper, glass, plastic, wood or cardboard. This is possible because the sensor can detect more than one type of material unlike the inductive proximity switch. Additionally, it sets them different since the permittivity values of plastic and paper are different.

The moving component of the system is the garbage belt. In order to ensure that the belt revolves in a circular direction, the system consists of a minimum of two pulleys together. Pulleys provide power, which causes the belt and the object on it to advance. An idler pulley is one that is not powered, and a driver pulley is one that is powered. Servo Motor: Waste gets directed to the appropriate containers using it. Servomotors are classified as "accurate control of angular or linear position, velocity, and considered by rotary or linear actuators. A sensor and a suitable motor are connected to get position feedback. The position intended for the output is represented by the digital or analog input control signal.

A microcontroller board developed by Arduino.cc, the Arduino Uno is available as an open-source project and is based on the Microchip ATmega328P. The open-source, programmable Arduino UNO microcontroller board is cheap, flexible, and simple to use. It can be used in a wide range of electronic applications. In this analysis, Arduino Uno is used to manage and control the waste segregation process through sensors and IoT.

The presented model's process diagram is displayed in Figure 2. The smart bin is used for storing trash, and the municipality collects these dustbins. The collected waste is placed over Garbage Belt. When the trash belt system detects garbage, it starts to move. To direct the dry, wet, and metallic waste into the correct bins, servo motors are used. Sensors that use inductive proximity are used to identify metallic garbage. The capacitive proximity sensor is used to differentiate between plastic and paper in the dry waste.

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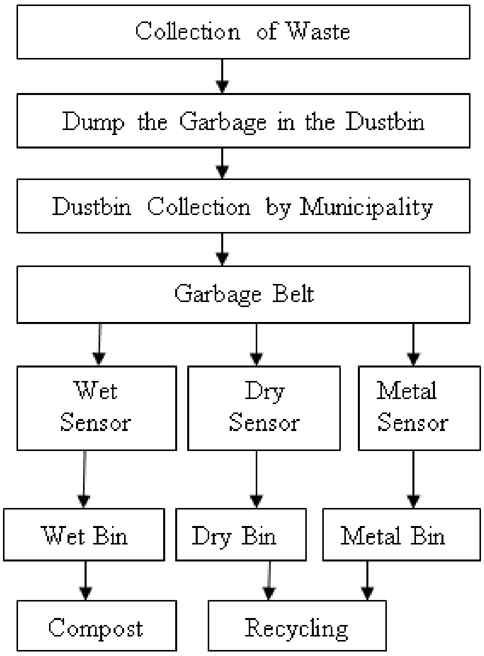

Figure 2: Workflow Diagram

A moisture sensor is used to check the wet waste. Waste that doesn't break down is referred to as dry waste. It is also referred to as non-biodegradable garbage. Dry trash is made up of materials that can be further recycled into new products, such as paper, glass, thermocol, Styrofoam, rubber, metal, cloth, empty bottles, and stationery. Glass and other sharp items should be kept in a different bag or container before being divided. Everything they produce in the kitchen is considered wet waste. For example: fruit, leftovers, coconut shells, vegetable peels, bread, biscuits, expired food, so on. This garbage is organic and can be recycled to make compost. The kitchen generates the most of the wet trash. The type of waste that cannot decompose properly is called dry waste. Wet waste can be recycled and transformed into new products that can be used again. Dry and metallic waste are recycled once the wet waste has been collected.

IV. RESULT ANALYSIS

In this section, smart waste segregation management system using three sensors is implemented. This is a representation of an outcome analysis for a recently developed smart waste management system. Figure 3 compares categorization smart waste management utilizing the advanced methodology and model that is shown.

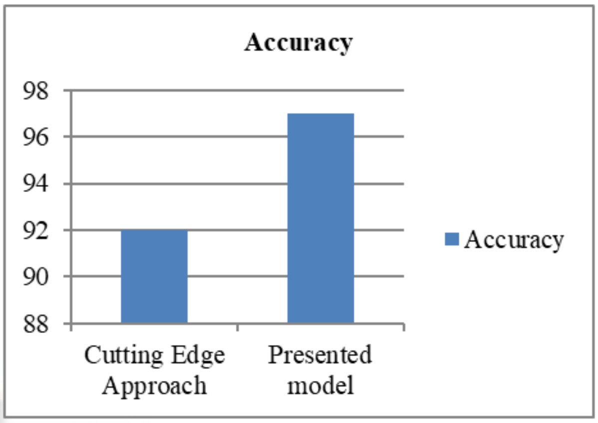

Figure 3: Waste Segregation Accuracy

Presented model has segregated the waste as dry waste, Metal waste and Wet waste. The classification accuracy of presented model is very high compared to cutting edge approach. The Figure 4 shows the Recycling rate comparison.

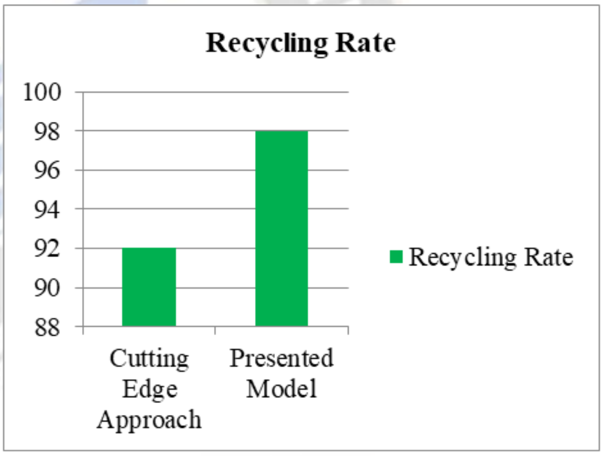

Figure 4: Recycling Rate Comparison

The waste recycling rate of presented model is higher than cutting edge approach. Hence presented smart dustbin Management system using Internet of Things has collected, classified and recycled the waste very accurately.

V. CONCLUSION

In this work, smart waste segregation management system using three sensors is presented. The main components included in this system are Capacitive proximity sensor, Inductive Proximity Sensor, motors, garbage belt, Arduino Uno and bins. The relevant municipal authorities are subsequently informed to empty the waste. After the collection of dustbin, collected waste is placed over garbage belt for waste classification. Various sensors, such as capacity proximity sensors, are used to identify the three types of garbage: metallic waste, moisture sensors, and inductive proximity sensors. Classified waste is loaded into the proper waste container using the servo motor. Finally, the wet waste is composed and dry, metallic waste is recycled. The performance of presented smart dustbin model is tested in terms of Dustbin Overflow rate, delay in dustbin collection, waste Classification Accuracy and Recycling rate of waste. Compared to earlier approaches, presented dustbin model has shown better performance. Therefore, by recycling and reusing waste, this model will be very helpful in the long term to maintain a clean environment in society and help it become a "green" and "smart" civilization.

REFERENCES

[1] S. N., P. M. Fathimal, R. R. and K. Prakash, "Smart Garbage Segregation & Management System Using Internet of Things(IoT) & Machine Learning(ML)," *2019 1st International Conference on Innovations in Information and Communication Technology (ICIICT)*, Chennai, India, 2019, pp. 1-6, doi: 10.1109/ICIICT1.2019.8741443.

[2] Siddappaji, K. Sujatha and R. C. Radha, "Technologies for segregation and management of solid waste: A review," *2016 International Conference on Emerging Trends in Engineering, Technology and Science (ICETETS)*, Pudukkottai, India, 2016, pp. 1-4, doi: 10.1109/ICETETS.2016.7603046.

[3] M. Pamintuan, S. M. Mantiquilla, H. Reyes and M. J. Samonte, "i-BIN: An Intelligent Trash Bin for Automatic Waste Segregation and Monitoring System," *2019 IEEE 11th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM)*, Laoag, Philippines, 2019, pp. 1-5, doi: 10.1109/HNICEM48295.2019.9072787.

[4] I. Aleksandrova and A. Gubernatorov, "Tools for Implementing the Financing Mechanism for the Waste Processing Industry," *2020 13th International Conference "Management of large-scale system development" (MLSD)*, Moscow, Russia, 2020, pp. 1-5, doi: 10.1109/MLSD49919.2020.9247835.

[5] 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," *2018 International Conference on ICT for Smart Society (ICISS)*, Semarang, Indonesia, 2018, pp. 1-6, doi: 10.1109/ICTSS.2018.8550013.

[6] A. P. Byzov, S. V. Efremov and F. A. Gomazov, "Social and Economic Aspects of Acceptable Risk of Ensuring Ecological Safety at Management of Municipal Waste," *2018 IEEE International Conference"Management of Municipal Waste as an Important Factor of Sustainable Urban Development" (WASTE)*, St. Petersburg, Russia, 2018, pp. 60-62, doi: 10.1109/WASTE.2018.8554106.

[7] V. G. Burlov, A. V. Andreev and M. I. Grachev, "On the Possibility of Using Web-Technologies to Provide Safety of Transportation of Municipal Wastes of Municipal Education," *2018 IEEE International Conference"Management of Municipal Waste as an Important Factor of Sustainable Urban Development" (WASTE)*, St. Petersburg, Russia, 2018, pp. 52-54, doi: 10.1109/WASTE.2018.8554178.

[8] T. S. Vasagade, S. S. Tamboli and A. D. Shinde, "Dynamic solid waste collection and management system based on sensors, elevator and GSM," *2017 International Conference on Inventive Communication and Computational Technologies (ICICCT)*, Coimbatore, India, 2017, pp. 263-267, doi: 10.1109/ICICCT.2017.7975200.

[9] N. N. Ahamad, S. Y. Mohamad, N. S. Midi, S. H. Yusoff and F. A. Rahman, "Discrimination of Residual and Recyclable Household Waste for Automatic Waste Separation System," *2018 7th International Conference on Computer and Communication Engineering (ICCCE)*, Kuala Lumpur, Malaysia, 2018, pp. 372-374, doi: 10.1109/ICCCE.2018.8539337.

[10] Yinghao Chu, Chen Huang, Xiaodan Xie, Bohai Tan, Shyam Kama, and Xiaogang Xiong, “Multilayer Hybrid Deep-Learning Method for Waste Classification and Recycling,” Computational Intelligence and Neuroscience vol. 2018, pp. 1-9, 2018, doi:10.1155/2018/5060857

[11] Y. Li, Y. Fang, P. Lou and J. Yan, "Design and implementation of a hazardous wastes proportioning management system," *2018 IEEE 15th International Conference on Networking, Sensing and Control (ICNSC)*, Zhuhai, China, 2018, pp. 1-6, doi: 10.1109/ICNSC.2018.8361276.

[12] A. Prakash, N. Agarwalla, R. Priyadarshini and R. Misra, "A Novel Approach Towards Industrial Waste Management Using Q-Learning," *2019 International Conference on Intelligent Computing and Remote Sensing (ICICRS)*, Bhubaneswar, India, 2019, pp. 1-6, doi: 10.1109/ICICRS46726.2019.9555893.

[13] Y. Xu, M. Sahnoun, M. Mazar, F. B. Abdelaziz and A. Louis, "Packaged Bio-Waste Management Simulation Model Application: Normandy Region, France," *2019 8th International Conference on Modeling Simulation and Applied Optimization (ICMSAO)*, Manama, Bahrain, 2019, pp. 1-5, doi: 10.1109/ICMSAO.2019.8880427.

[14] Z. Wang, Y. Teng, H. Jin and Z. Chen, "Urban Waste Disposal Capacity and its Energy Supply Performance Optimal Model Based on Multi-Energy System

Coordinated Operation," in *IEEE Access*, vol. 9, pp. 32229-32238, 2021, doi: 10.1109/ACCESS.2021.3060421

[15] M. Al-Jabi and M. Diab, "IoT-enabled citizen attractive waste management system," *2017 2nd International Conference on the Applications of Information Technology in Developing Renewable Energy Processes & Systems (IT-DREPS)*, Amman, Jordan, 2017, pp. 1-5, doi: 10.1109/IT-DREPS.2017.8277804.

[16] T. J. Sheng et al., "An Internet of Things Based Smart Waste Management System Using LoRa and Tensorflow Deep Learning Model," in *IEEE Access*, vol. 8, pp. 148793-148811, 2020, doi: 10.1109/ACCESS.2020.3016255.

[17] S. Ahmad, Imran, N. Iqbal, F. Jamil and D. Kim, "Optimal Policy-Making for Municipal Waste Management Based on Predictive Model Optimization," in *IEEE Access*, vol. 8, pp. 218458-218469, 2020, doi: 10.1109/ACCESS.2020.3042598.

[18] Imran, S. Ahmad and D. H. Kim, "Quantum GIS Based Descriptive and Predictive Data Analysis for Effective Planning of Waste Management," in *IEEE Access*, vol. 8, pp. 46193-46205, 2020, doi: 10.1109/ACCESS.2020.2979015.

[19] Sonal K Jagtap, Balaji K Vasurkar, “Smart Waste Management System in Smart Cities Using IOT,” International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering, Vol. 6, Issue 6, June 2018, doi: 10.17148/IJIREEICE.2018.663

[20] Yuan, Yujun, Tong Li, and Qiang Zhai, "Life Cycle Impact Assessment of Garbage-Classification Based Municipal Solid Waste Management Systems: A Comparative Case Study in China," International Journal of Environmental Research and Public Health, vol. 17, no. 15, 2020, doi: 10.3390/ijerph17155310

[21] Caruso, Giulia, and Stefano Antonio Gattone, "Waste Management Analysis in Developing Countries through Unsupervised Classification of Mixed Data" Social Sciences, vol. 8, no. 6, 2019, doi:10.3390/socsci8060186

[22] Z. Wang, Y. Teng, H. Jin and Z. Chen, "Urban Waste Disposal Capacity and its Energy Supply Performance Optimal Model Based on Multi-Energy System Coordinated Operation," in *IEEE Access*, vol. 9, pp. 32229-32238, 2021, doi: 10.1109/ACCESS.2021.3060421.

[23] 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, India, 2017, pp. 199-203, doi: 10.1109/ICCCT2.2017.7972276.

[24] M. Adam, M. E. Okasha, O. M. Tawfeeq, M. A. Margan and B. Nasreldeen, "Waste Management System Using IoT," 2018 International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE), Khartoum, Sudan, 2018, pp. 1-4, doi: 10.1109/ICCCEEE.2018.8515871.

[25] Sunday A. Afolalu, Ayodeji A. Noiki, Omolayo M. Ikumapayi, Adebayo T. Ogundipe, Olamilekan R. Oloyede, “Development of Smart Waste Bin for Solid Waste Management,” International Journal of Sustainable Development and Planning, vol. 16, no. 8, pp.1449-1454, December 2021, doi: 10.18280/ijsdp.160805