Design and Development of an Intelligent Waste Management System for Smart Cities

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***Abstract*—Smart bin technology is revolutionizing waste management by helping municipalities optimize waste collection and minimize unnecessary stops at empty dumpsters, thereby saving both time and energy. Traditional waste collection routes are often inefficient, but smart bins address this issue using wireless ultrasonic sensors that monitor fill levels in real time. In this study, a smart bin has been designed with multiple advanced features, with its primary function being automated garbage segregation. Additionally, it includes ultrasonic sensors that detect when a person approaches, allowing the bin's lid to open automatically for a hands-free, more hygienic disposal experience. The system also provides analytical insights, informing users about the quantity and type of waste they dispose of. Moreover, a mobile app connected to the bin sends reminders to users when it is time to take out the garbage. By enabling proper waste segregation, the smart bin helps distinguish between recyclable and non-recyclable waste, promoting efficient waste management. The bin is integrated with smart components like sensors and an Arduino system, ensuring seamless operation. The lid automatically opens when an object is detected nearby and closes after a predetermined time, making waste disposal effortless and sanitary.**

***Index Terms*—Smart Bin, Solid waste Management, Smart City, Arduino Uno and Sensors.**

I. INTRODUCTION

Solid waste management refers to the systematic process of collecting, treating, and disposing of solid waste while also promoting recycling and resource recovery. Throughout history, waste generation has been a persistent issue in human settlements, necessitating efficient management solutions. The goal of solid waste management is to transform waste into a valuable resource while minimizing its environmental impact.

Every household and business should actively participate in proper waste management practices to ensure sustainability. While industrialization has significantly contributed to economic growth and technological advancements, it has also led to an increase in solid waste production. The improper disposal of municipal solid waste can result in unsanitary conditions, environmental pollution, and the spread of vector-borne diseases through rodents and insects. Therefore, effective solid waste management is essential to maintaining public health and preserving the environment.

A smart city utilizes information and communication technology (ICT) to enhance operational efficiency, facilitate seamless information sharing with the public, and deliver improved government services, ultimately ensuring better citizen welfare and sustainable urban development.

The primary objective of a smart city is to optimize urban functions, enhance public services, and foster economic growth while significantly improving the quality of life for its residents through the integration of smart technologies and data-driven decision-making. The true value of a smart city lies not merely in the availability of advanced technology but in its effective utilization to create a more efficient, sustainable, and connected urban environment.

A city's level of smartness is determined based on several key characteristics, including:

1. A robust infrastructure centered around advanced technology and digital connectivity.
2. Strong environmental initiatives aimed at sustainability, energy efficiency, and pollution control.
3. Well-planned, efficient, and highly functional public transportation systems that reduce congestion and emissions.

4. Confident, forward-thinking urban planning strategies that drive long-term development and resilience.
5. A thriving community where people can live, work, and engage with the city's resources efficiently while benefiting from improved safety, healthcare, and education services.

Smart bins represent an advanced waste management solution, integrating intelligent technology to enhance efficiency and sustainability. These bins are equipped with wireless ultrasonic fill-level sensors that continuously monitor waste levels. Through the Internet of Things (IoT), this data is transmitted to a cloud-based monitoring and analytics platform, enabling real-time waste management insights.

Designed to facilitate waste segregation, smart bins utilize embedded sensors, image recognition, and artificial intelligence to differentiate various types of waste. They incorporate IoT-enabled sensors that serve as real-time indicators to assess bin capacity, allowing waste collection schedules to be optimized accordingly. With the global population increasing at an exponential rate, conventional waste management methods—where cleaning schedules are predetermined—often prove inefficient. In many cases, bins may either remain partially empty when waste collectors arrive or overflow long before scheduled collection times, leading to environmental hazards and increasing the risk of bacteria- and virus-borne diseases.

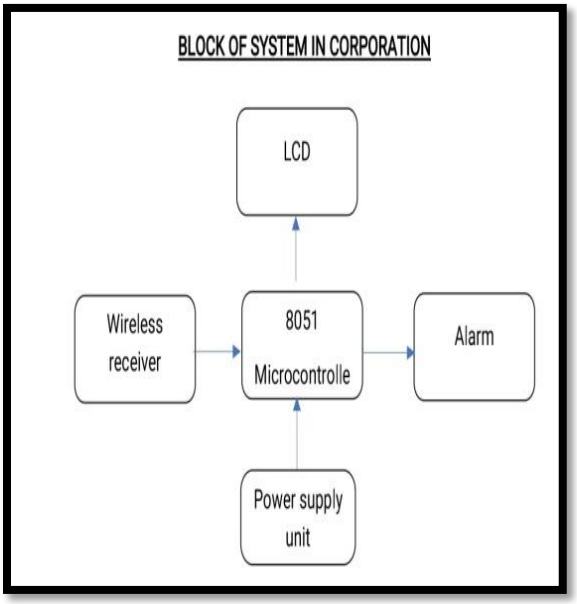

Fig. 1. Block of System in Corporation

As the concept of smart cities continues to expand worldwide, urban development demands innovative and efficient solutions. A smart city promotes a smart lifestyle, where cleanliness and hygiene play a crucial role. To achieve this, technology-driven waste management strategies must be implemented globally, ensuring cities become cleaner, greener, healthier, and more sustainable. In India, improper waste disposal is a common challenge in both urban and rural areas, significantly contributing to pollution. Indian cities alone generate over 100 million tons of solid waste annually, emphasizing the urgent need for smarter, technology-driven waste management solutions.

Through our project, we aim to develop and implement a smart system integrated into a dustbin to prevent overflow, which can lead to unsanitary conditions and the spread of various diseases. By incorporating technology-driven solutions, our system also promotes environmental cleanliness and enhances urban hygiene.

The system architecture consists of multiple interconnected components, including an LCD display, LED indicators, a buzzer, infrared sensors, an 8051 microcontroller, a power supply, and a Wi-Fi module (Node MCU). These components work together to efficiently monitor and manage waste disposal.

1. Infrared sensors detect the level of garbage inside the bin in real time.
2. LED indicators illuminate at different levels to visually indicate how much of the bin's capacity has been utilized.
3. The LCD screen provides a clear display of the bin’s current fill level, ensuring easy monitoring.
4. When the trash bin reaches 80% of its capacity, an alert system is triggered, activating a buzzer to notify nearby users or waste management personnel.
5. Simultaneously, a notification message is sent via the Wi-Fi module (Node MCU) to the designated device, informing authorities or waste collectors that the bin is nearing full capacity.

This smart waste management system enhances efficiency by ensuring timely garbage collection, reducing the risk of overflow, and promoting a cleaner, healthier, and more sustainable environment.

II. LITERATURE REVIEW

2.1 Daval Patel 2019, Smart Dustbins for Smart Cities.
Our project offers an IT-based solution for garbage collection and management by integrating a Fill Alerting System utilizing an Ultrasonic Sensor, Arduino Uno, Buzzer, and Wi-Fi Module. The system ensures that dustbins are cleaned as soon as the garbage level reaches its maximum capacity. Additionally, an alarm is triggered when wet waste is mistakenly disposed of in a dry waste bin, ensuring proper waste segregation.
If a dustbin is not cleaned within the predefined time, an automated message is sent to higher authorities, prompting them to take appropriate action against the responsible sweeper or contractor. The system also helps in preventing fake reports, as historical cleaning data is always available, thereby reducing corruption in waste management. Furthermore, by implementing an efficient algorithm, the system optimizes waste collection routes, reduces the number of collection van trips, and saves both operational costs and resources.

2.2 Bikaramjit Singh 2018, Smart Dustbin Management.
One of the utilities of our system is that the Govt. can use the garbage generations statistics for policy and program design. If the system is implemented properly, it will really make the cities cleaner and greener and makes the smart city a reality. The smart dustbin management by using sensors and dustbin location by using GPS.
2.3 Ashok Kumar Das2018, The Smart Waste Management Solution Geared Towards Citizens.
The society model of the 21st century has been increasingly influenced by cities in their context.
According to the United Nations data, by 2050, approximately 70% of the population will live in urban centers, and this rapid growth of people living in cities has been of great concern, since towns do not always grow in a sustainable way. In this regard, smart city design has been increasingly studied and discussed around the world to solve this problem. Following this approach, this paper presented nescient IoT-based and real-time waste management model for improving the living environment in cities, focused on a citizen perspective. The proposed system uses sensor and communication technologies where waste data is collected from the smart bin, in real-time, and then transmitted to an online platform where citizens can access and check the availability of the compartments scattered around a city.
2.4 Mohan Panjabi and Karan Patel 2017, Digital Dustbin-Smart Bin for a Smart Cities.The system integrated here is user-friendly as well as eco-friendly as it works fully on solar energy. It will be easier to attract users and thus, the mission of cleanliness can be well accomplished. Many terrorist attacks can be prevented by these dustbins. The only thing which makes this model unique is its focus is balanced between user and objective achievement. Looking forward to the future scopes we can also interface various ID proof linking other than Aadhar Card, reduced its response Digital Dustbin - Smart Bins for Smart Cities 65 Published By: Blue Eyes Intelligence Engineering & Sciences Publication Retrieval making water proof circuit and body design, building a Human Machine Interface using controller and advanced nuclear detector.
2.5 Manish Singh 2016, Smart Bin Implementation for a Smart Cities.
Our Survey presents IOT based smart waste management System by imposing Sensors to monitor the status of smart bin and by doing so we gather the information of the garbage. Due to this information, we can control the overflow of the garbage in public areas and the pollution which generally occurs around the bins. This System can segregate and decompose the decomposable waste material which will be useful for the users mainly who belong to the agriculture field.

III. MATERIALS

In our project, we aim to focus on highly populated and busy areas to collect essential data related to sewage collection and waste management. This includes gathering information on the population size, number of households, and the estimated amount of waste generated per house. Additionally, we will classify the waste into different categories such as domestic waste, paper, glass, and plastic waste to ensure efficient waste segregation.
While numerous research projects on waste management exist in the literature, our approach integrates smart sensors for real-time monitoring of waste accumulation in bins. These sensors will transmit fill-level data wirelessly to a cloud server,

where the information will be stored and forwarded to waste management authorities for timely action.

The smart city garbage collection and monitoring system in this project is built on a microcontroller-based platform, interfacing with Global System for Mobile Communication (GSM), ultrasonic sensors, and weight sensors. The weight sensor, placed at the bottom of the bin, calculates the total waste collected, while the ultrasonic sensor, positioned at the top, determines the fill status of the bin. This technology-driven approach ensures efficient waste collection, timely disposal, and improved urban sanitation, contributing to a cleaner and smarter city environment.

3.1. Required Programming Language

1. Raspberry Pi

3.2 Required Hardware

1. Arduino Uno	2. Ultrasonic Sensor
3. IR Sensor	4. Odour Sensor
5. Transducer	6. Microcontroller
7. Printed Circuit Board	8. Resister
9. Flame Sensor	10. Secure Digital Cards
11. Plastic Outer Cover	12. Wier
13. Power Supply	14. Dustbin

IV. PROCEDURE

Now, let's go through the actual setup and build process of the Smart Dustbin using Arduino. The first step involves designing the lid-opening mechanism. As expected, a Servo Motor is used to control the automatic opening and closing of the lid.

To achieve this, a small plastic tube (such as an empty ballpoint pen refill) is firmly attached to the servo horn (single-ended horn) using instant glue. This setup allows the servo motor to exert the necessary force to lift the lid when required. For proper functioning, the servo mechanism must be positioned near the lid to ensure smooth and efficient operation.

The Smart Dustbin system is built around Arduino, integrating various sensors and components to automate waste disposal. The servo motor-driven lid mechanism enhances hygiene and convenience, making waste disposal hands-free and efficient.

3.3.1 Ultrasonic Sensor Connecting: After successfully servo motor is placed now it's time for sensor, so HC-SR04 Ultrasonic sensor is placed at the front of the dustbin.

The final step in the build process is to make the necessary connections using long connecting wires as per the circuit diagram and securing these wires so that they don't hang around. All the wires from both the components i.e. Ultrasonic Sensor and Servo Motor are connected to respective pins of Arduino. This finishes up the build process of the Smart Dustbin. In Arduino Code has been submitted, and with all hardware and software. Connection in Dustbin. We will run our dustbin, wait its working or not.

V. CIRCUIT DIAGRAM

Arduino Uno board consist ATmega328 P microcontroller, it is important component of UNO board. In this other component are present like a power supply, ultrasonic module and servo motor etc. The ultrasonic sensor echo pin and trigger pin is connected to pin digital pin D7 and D8. The +Vcc pin is connected to +5V supply and GND pin is connected to ground pin of arduino Uno board. The control (PWM) pin of servo motor is connected to digital pin D9 of arduino. Hence, servo motor is used to open the cap of dustbin. For this project and components used, the preset level of distance between dustbin and hand is fixed to 40 cm.

Ultrasonic Sensor: This sensor is used in to locate the distance between the smart dustbin and hand/object come near to it. The principle behind finding distance of obstacle is sonar wave. It only detects obstacle when Trigger pin receive high pulse for the period more than 10 us. When this sensor verifies the presence of hand (obstacle) it starts to send eight cycles of ultrasonic burst at 40 KHz and then it waits for reflected ultrasonic signal. Ultrasonic sensor module has two drums. One of the drums is used for transmitting the pulse of ultrasonic and the second drums are for receiving the ultrasonic signal. When ultrasonic detect/sense object, the echo pin of module is set high. Waiting period of reflected pulse is completely dependent upon the location of obstacle. When the echo signal is obtained, we can calculate the distance by using the formula Distance (in cm) = (duration/2) / 29.1 Circuit Diagram Initially, the cap of dustbin is switched back to zero-degree position (Close) by the servo motor.

The controller keeps on monitoring the signal receive from ultrasonic module. When ultrasonic module detects an obstacle, the controller check if it crosses a

threshold distance value set for open the cap of dustbin. As soon as that happens, the controller triggers the servo motor when then open the cap for limited line (as set in code part). For this system prototype set time is given for 2 second. Here in this project also used an ON/OFF switch, in order to activate and de-activated the smart dustbin whenever require as per situation. A pull-up resistor of 10K is connected in series of switch as shown in circuit diagram in order to solve the de-bouncing problem. We can also use Arduino NANO instead of Arduino Uno. Do not have to change source code because the board use identical pin for controlling servo motor, switch and ultrasonic sensor. The simplest part of the project smart dustbin using arduino is software part because it is clean, simple and easy to understand. The program checks the distance had also used "Servo's" inbuilt library function for servo operation.

Proposed Block Diagram of SWM

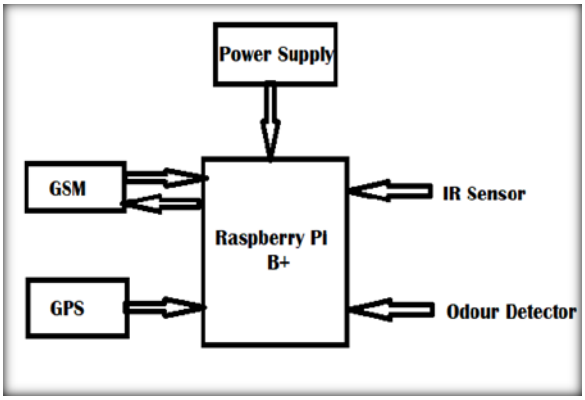

Fig. 2. Proposed Block Diagram of SWM

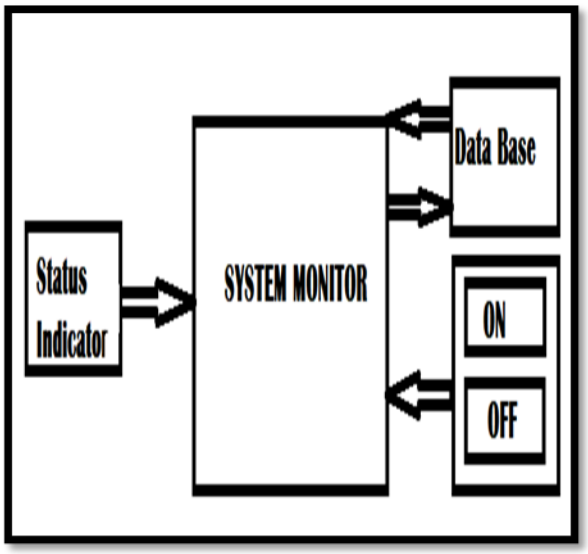

Fig. 3. Block Diagram of IoT Section

VI. WORKING

After wiring and attaching all the devices and setting up to the Smart Dustbin, now observe all the important setup whether they are well connected or something missed. After connection set up now next step is to submit/upload code in Arduino and supply power to the circuit. When system is powered ON, Arduino keeps monitoring for any things that come near the sensor at give range. When Ultrasonic sensor detect any object for example-like hand or others, here Arduino calculates its distance and if it less than a certain predefines value than servo motor gets activate first and with the support of the extended arm of the lid. Lid will open for a given time than it will automatically close.

After all hardware and software connection, now Smart Dustbin program will be run. Dustbin lid will when someone comes near at some range than wait for user to put garbage and close it. It's properly running or not. For social it will help toward health and hygiene, for business for we try to make it affordable to many as many possible. So that normal people to rich people can take benefit from it.

We have designed a smart dustbin using ARDUINO UNO, ultrasonic sensor which will sense the item to be thrown in the dustbin and open the lid with the help of the motor. It is an IOT based project that will bring a new and smart way of cleanliness. It is a decent gadget to make your home clean, due to practically all offspring of home consistently make it grimy and spread litter to a great extent by electronics, rappers and various other things. Since the smart dustbin is additionally intriguing and children make fun with it so it will help to maintain cleanliness in home. It will be applied for various type of waste. Dustbin will open its lid when someone/object is near at some range then it will wait for given time period than it will close automatically. Here lid will close when you don't want to use and it will only open when it required. Here in this project also used an ON/OFF switch, in order to activate and de-activated the smart dustbin whenever require as per situation. A pull-up resistor of 10K is connected in series of switch as shown in circuit diagram in order to solve the de-bouncing problem. We can also use Arduino NANO instead of Arduino Uno. Do not have to change source code because the board use identical pin for controlling servo motor, switch and ultrasonic sensor.

VII. DESIGN OF A SMART DUST BIN

The system design tries to be cost-effective and user friendly. The design relied on a commonly used outdoor trash bin, which is redesigned to append an extension arm to hold the solar cell panel. The metal work also included adding an 18cm × 22cm tray for holding any electronic device during charging from the USB port, which will be attached to the extension arm. The height of the bin from the ground to the end of solar cell panel is 155cm. The trash container has a cylindrical shape of 30cm diameter and 46cm height. However, the height from the bottom of the bin opening is 27cm, which gives a volume of 76341cm3. Moreover, all the electronic parts will be mentioned in the next section are held inside (110×180×77mm) plastic electric junction box, which held underneath the bin lid. This design is applicable to almost any standard outdoor trash bin.

4.1 HARDWARE The system structure relies on Arduino Nano board. According to the datasheet, it is based on ATmega328 microcontroller which has a 16MHz clock speed, 32 KB flash memory, 2KB SRAM and 1KB EEPROM. Arduino Nano is a microcontroller breadboard with integrated 5V voltage regulator and can provide serial communication over USB with a computer for programming. It also has 14 digital I/O pins; 6 of them can provide PWM output and 2 external interrupt pins. This microcontroller supports SPI and I2C communications. Moreover, it also has 8 analog I/O pins. All these pins can original article | doi: 10.25007/ajnu. v6n3a103 Academic Journal of Nawroz University (AJNU) deliver or accept a maximum of 40 mA and has an internal pull-up resistor 20-50 kΩ. All the above comes in a small package of 18 x 45 mm and weighs 4g. This microcontroller breadboard was chosen for its size, weight, functionality and its programming flexibility. Figure 4 and Figure 5 shows the system schematic of the circuit board and how the following electronic parts are connected inside the electric junction box. Ultrasonic ranging module sensor (HC-SR04) is used to detect the fullness level of the trash bin. According to the datasheet, this sensor can detect a 0.5m2 object from a range of 20- 400cm with a 15-degree measuring angle. Moreover, it can detect liquid and solid objects, and also immune to almost any outdoor interference sources. This sensor returns Time of Flight (ToF) which is the time interval that ultrasonic wave takes to cross back and forward between the wave source and the material boundary [14]. $Distance = ToF \times SpeedofSound$ 2 The system depends on GSM module (sim900a mini v3.8.2) to send SMS fullness alerts. according to the datasheet, the module can be controlled by sending AT commands over its 5V serial port. The Rx pin of GSM module is connected to analog pin A3 on the Arduino Nano, and the Tx pin of the module is connected to A4 pin of the Arduino board. A3 and A4 pins will be turned into Tx/Rx pins using a software library, because of the GSM module relies on serial communication and Arduino Nano has no extra serial port. An LED, with a 1kΩ resistor, is used to give a visual alert when the bin is full. Moreover, a PIR motion detector (HC-SR501) is used to sense when the trash bin is being used. According to the datasheet, this sensor has a sensing range of 120 degrees within 7 meters. Therefore, the sensor is installed to the side of the plastic box and partially covered to sense only user hand entering the bin. The usage event is triggered by the PIR sensor. This sensor will interrupt the microcontroller work using pin 3 to play a WAV file stored on a MicroSD card, which is connected to the setup by an adapter from Wave share. The audio message is played over 3W/4Ω speaker driven by an HXJ8002 audio amplifier. The MicroSD card is also used to log the fullness and usage events inside CSV files for further analyses. Finally, the setup of the system is powered by off-the-shelf 12000mAh power bank, which will also be used to charge any electronic device provided by bin user. The power bank is backed up by 13W/5V solar cell panel which can supply current up to 2.6A.

4.2 SOFTWARE The whole program is done using Arduino IDE. Figure 6 shows a flow chart of the Arduino program. Four libraries were used to facilities communicating with the modules. Software Serial library is used to communicate with the GSM module and send AT commands to it. This library is used because of Arduino Nano does not have an additional serial port, which the GSM module rely on for communication with the microcontroller. This library transforms A3 and A4 pins into extra Tx and Rx pins to connect the Tx/Rx pins of the GSM module. SPI library is used for communicating with the MicroSD module which depends on Serial Peripheral Interface (SPI) data protocol. SdFat library is used to manage

data and read/write files on the MicroSD card. The last library is TMRpcm, which is used to output the WAV file, stored on the MicroSD, as PWM signal to digital pin 9 that connected to the speaker. The Setup function of the Arduino program first defines the used pins as outputs or inputs, then sends AT commands to the GSM module to enable text mode, enable local time/date stamp and store current settings on the GSM module memory. The time/date stamp will be stored on CSV files during logging events on. This function is also used to get the phone number and SMS alert text, which will be sent to that number in case of fullness event, from text files on the MicroSD card.

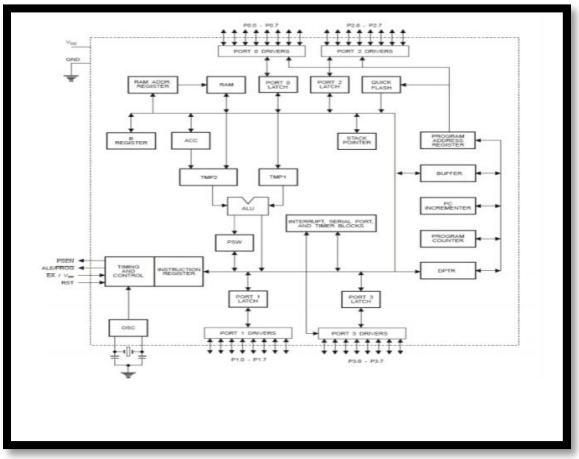

Fig 4: Shows the Circuit Connections of Smart

This step is done to simplify changing these parameters without altering the program. The final step of Setup function is initializing digital pin 3 as an interrupt pin to connect the output pin of the PIR microcontroller will be interrupted to play the WAV file on the speaker and log the usage event with the current time/date stamp on the CSV file. The Loop function is used to measure the distance between the ultrasonic module and the trash every 15 minutes. This time period can be changed hereafter to correspond with real life operating cases. A while loop will iterate while the measured distance is smaller than a threshold, which is measured 10cm according to the bin dimensions. The LED will blink for 5 seconds before a second measuring is taken inside the while loop to check if the measured value still satisfies the condition and no SMS alert has been sent. After that, the SMS alert message will be sent and the fullness event will be logged in the CSV file. Finally, as bookkeeping measure, the balance of the used SIM card is added to the SMS text before sending it. The balance is obtained by sending Unstructured Supplementary Service Data (USSD) code to the mobile network using AT command, which is executed by the GSM module.

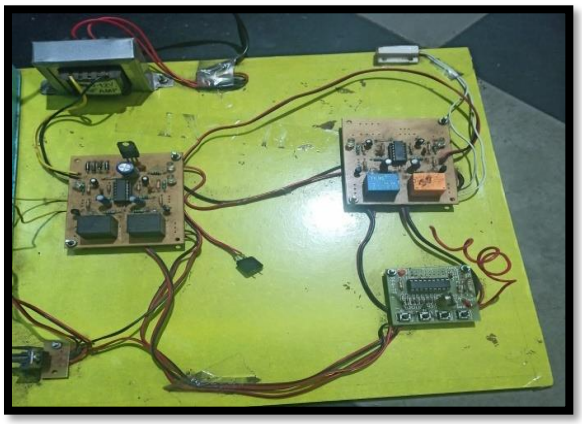

Fig 5: Shows the Circuit Connections of Smart

VIII. CONCLUSION

This project focuses on the implementation of an Automatic Garbage Fill Alerting System using Ultrasonic Sensors, Arduino Uno, Buzzer, and a Wi-Fi module. The system ensures timely cleaning of dustbins once they reach their maximum garbage level. It operates with a power supply from a Piezoelectric Device, making it energy-efficient. If the dustbin is not cleaned within a specific time frame, the system will alert the relevant authorities. The goal is to bring about an evolution in cleanliness with a combination of intelligent waste monitoring and trash compaction technologies, making smart dustbins more advanced and efficient compared to traditional garbage bins. Equipped with smart devices such as sensors and Arduino, the dustbin lid automatically opens when an object approaches, and after a set time, it closes.

This system promotes better health and hygiene for the community and aims to be affordable for a wide range of people, from ordinary citizens to affluent individuals. It is believed that this initiative will contribute significantly to improving cleanliness and technology in waste management. Moving forward, the next step will involve adding another sensor to detect when the dustbin is full, and a display will be incorporated to notify the user about the bin's status, ensuring efficient waste management.

IX. FUTURE ENHANCEMENT

The Automatic Garbage Fill Alerting System plays a crucial role in reducing pollution by addressing issues related to overflowing garbage bins. Often, overflowing dustbins attract animals like dogs and cows, and even birds, which rummage through the garbage. This project helps to avoid such situations by ensuring the dustbins are emptied in a timely manner. The system directly sends a notification to the cleaning vehicle rather than relying on the contractor's office, streamlining the waste collection process. Additionally, the system can differentiate between dry and wet waste bins, collecting plastic and biodegradable waste separately. To achieve this, methane and smell sensors can be used to identify the type of waste. This functionality helps in segregating waste at the source, reducing the need for manual labor.

X. ACKNOWLEDGMENT

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REFERENCES

[1] A. Arroub, B. Zahi, E. Sabir and M. Sadik, "A literature review on smart cities: Paradigms opportunities and open problems", Proc. Int. Conf. Wireless Netw. Mobile Commun. (WINCOM), pp. 180-186, Oct. 2016.

[2] J. W. Levis, M. A. Barlaz, J. F. DeCarolis and S. R. Ranjithan, "A generalized multistage optimization modeling framework for life cycle assessment-based integrated solid waste management", Environ. Model. Softw., vol. 50, pp. 51-65, Dec. 2013.

[3] S. E. Vergara and G. Tchobanoglous, "Municipal solid waste and the environment: A global perspective", Annu. Rev. Environ. Resour., vol. 37, no. 1, pp. 277-309, Nov. 2012.

[4] T. Anagnostopoulos, A. Zaslavsky, K. Kolomvatsos, A. Medvedev, P. Amirian, J. Morley, et al., "Challenges and opportunities of waste management in IoT-enabled smart cities: A survey", IEEE Trans. Sustain. Comput., vol. 2, no. 3, pp. 275-289, Jul. 2017.

[5] T. Anagnostopoulos, A. Zaslavsky, I. Sosunova, P. Fedchenkov, A. Medvedev, K. Ntalianis, et al., "A stochastic multi-agent system for Internet of Things-enabled waste management in smart cities", *Waste Manage. Res. J. Sustain. Circular Economy*, vol. 36, no. 11, pp. 1113-1121, Nov. 2018.

[6] Nellore, K.; Hancke, G. A survey on urban traffic management system using wireless sensor networks. Sensors 2016, 16, 157. [CrossRef] [PubMed].

[7] C-IST Platform. Certificate Policy for Deployment and Operation of European Cooperative Intelligent Transport Systems (C-ITS); European Commission: Brussels, Belgium, 2017.

[8] Jiang, D.; Delgrossi, L. IEEE 802.11p: Towards an international standard for wireless access in vehicular environments. In Proceedings of the VTC Spring 2008-IEEE Vehicular Technology Conference, Singapore, 11–14 May 2008; pp. 2036–2040.

[9] Chen, S.; Hu, J.; Shi, Y.; Peng, Y.; Fang, J.; Zhao, R.; Zhao, L. Vehicle-to-everything (V2X) services supported by LTE-based systems and 5G. IEEE Commun. Stand. Mag. 2017, 1, 70–76. [CrossRef].

[10] Savolainen, P.; Datta, T.; Ghosh, I.; Gates, T. Effects of dynamically activated emergency vehicle warning sign on driver behavior at urban intersections. Transp. Res. Rec. J. Transp. Res. Board 2010, 2149, 77–83. [CrossRef].

[11] Asaduzzaman, M.; Vidyasankar, K. A Priority Algorithm to Control the Traffic Signal for Emergency Vehicles. In Proceedings of the 2017 IEEE 86th Vehicular Technology Conference (VTC-Fall), Toronto, ON, Canada, 24–27 September 2017; pp. 1–7.

[12] A. V. de Souza Melaré, S. M. González, K. Faceli and V. Casadei, "Technologies and decision support systems to aid solid-waste management: A systematic review", *Waste Manage.*, vol. 59, pp. 567-584, Jan. 2017.