

Dr. DISPSOSE

A SMART BIN FOR DISPOSAL OF INFECTIOUS MEDICAL WASTE

Submitted in partial fulfillment of the requirements for the award of Master
of Technology degree in Medical Instrumentation

by

CHARAN MA (40440003)



DEPARTMENT OF BIOMEDICAL ENGINEERING

SCHOOL OF BIO AND CHEMICAL ENGINEERING

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **CHARAN MA** (Reg. No. **40440003**) who carried out the project entitled "**Dr. Dispose- A Smart Bin for Disposal of Infectious Medical Waste**" under our supervision from **September 2021 to March 2022**.

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DECLARATION

I **CHARAN MA** (Reg. No. **40440003**) hereby declare that the Project Report entitled “**Dr. Dispose- A Smart Bin for Disposal of Infectious Medical Waste**” done by me under the guidance of Ms. **SINDU DIVAKARAN**, M.E., (Ph.D.,) Department of Biomedical Engineering is submitted in partial fulfillment of the requirements for the award of **Master of Technology** degree in **Medical Instrumentation**.



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ABSTRACT

Healthcare wastes have increased tremendously during this pandemic and it aids in transmission of COVID virus easily. The COVID isolation wards, quarantine rooms, and home quarantined people are generating waste every day. When the waste is uncollected, the bin that remains full inside the ward is a common problem nowadays. The bins are cleaned and waste is collected only by routine schedules in the hospitals. The key issue of inadequate waste management is that the garbage bin in the hospital wards gets overflowed in advance before the commencement of the next cleaning process and this may cause an exponential higher threat of community spread of COVID-19. Thus, an efficient IoT-based waste management system is essential to get the real-time status of the garbage level inside the wards and prevent the risk of contamination to the cleanliness staff from infectious disease. Our project aims to find a solution by using IoT based smart bin system to display the level of garbage collected in the bins of COVID wards by using an 'Ultrasonic Sensor' to prevent overflow of garbage from the smart bins and a 'Gas sensor' to sense the presence of hazardous gases. It has ultraviolet (UV) lights that can neutralize the virus and other pathogens. The system is powered by a long-lasting rechargeable battery which gets charged by a solar Piezo hybrid power charging system. Thus, 'Dr. Dispose' tends to reduce the risk of transmission of infectious disease to healthcare workers. It is a simple yet very useful concept, where smart bins will move prevention of overflowing garbage from the Bins and also ceasing unhygienic conditions from prevailing near it.

Keywords: Internet of Things, COVID Waste management, Sensors, Solar Piezo hybrid Power, pathogens.

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LIST OF ABBREVIATIONS

GIS	Geographic Information System
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile communications
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
MSWM	Municipal Solid Waste Management
RFID	Radio Frequency Identification
UART	Universal Asynchronous Receiver/Transmitter
WEEE	Waste Electrical and Electronic Equipment
WSN	Wireless Sensor Network

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Solid waste which is one of the sources and causes of environmental pollution has been defined under Resource Conservation and Recovery Act as any solid, semi- solid liquid or contained gaseous materials discarded from industrial, commercial, mining or agricultural operations and from community activities (Bashir & Banday, 2013). Most daily human activities generate waste which requires to be properly managed to protect human health and environment while enhancing aesthetics. This scenario is particularly evident in urban settlements which generate large quantities of solid waste due to high human population (National Environment Management Authority, 2014).

Waste management is a task which occurs in a great variety of domains and contexts. Moderate amounts of waste can be found in any environment inhabited by human beings (Prassler, Stroulia, & Strobe, 1997). Waste management is an important requirement for ecologically sustainable development in many countries. Efficient management/ clearing of waste is a major issue in today's society (Glouche & Couderc, 2013). The impacts of poor solid waste management within the urban settlements, particularly cities and big municipalities can be disastrous (National Environment Management Authority, 2014).

Common methods of solid waste disposal is the use of waste bins for collection (Lazaro, Alexis, & Rubio, 2014). The office and domestic waste products are collected through waste bin at a common place at a particular spot. A major difficult task is the process of checking waste bins for the collection of waste (Bashir & Banday, 2013). The common waste collection process demands that waste management personnel has to pass by and collect waste from all the different waste bins. The waste management personnel has to present himself in person at all the waste collection points without the knowledge of the bin status. In this case, two possibilities present; either there is no waste for collection, or the bin has over flown.

This is a complex and time consuming process. Rising waste disposal costs and high visibility of waste collection operations are forcing residents to demand efficient collection and disposal of solid waste (Dugdhe, Shelar, Jire, & Apte, 2016). As such there is need for proper and efficient waste management (Bashir & Banday, 2013). Cleaning of garbage bin in time will ensure proper cleanliness of the surrounding (Thakker, 2015)

Solid waste collection is one of the most expensive services provided by a city to its residents. Between 75-80% of the solid waste management budget is spent on collection and transfer costs. Therefore, productivity of collection and transfer operations is of significant concern (Dugdhe et al., 2016). Table 1.1 presents a summary of generation of waste in various Major towns in Kenya:

TABLE 1.1: Summary of Wastes Generation, Collection and Recovery Status in Major Towns

(Adapted from National Environment Management Authority, 2014)

	Estimated Waste generated (tones/day)	% Waste collected	% waste Recovery	Uncollected waste
Nairobi	2400	80%	45%	20%
Nakuru	250	45 %	18%	37%
Kisumu	400	20%	Unknown	Unknown
Thika	140	60%	30%	40%
Mombasa	2200	65%	40%	35%
Eldoret	600	55%	15%	45%

Urban/suburban waste management involves numerous waste bins that exhibit significant filling variations (over days and seasons or location) and diverse requirements for emptying, from sporadic (a few times within a week) to very frequent (several times a day). On the other hand other waste forms (i.e. agricultural, biomedical, chemical, electronic, mineral, organic/inorganic, and radioactive, etc.)

The problem of efficient waste management is one of the major problems of the modern times, thus there is an utmost need to address this problem(Bashir &

Banday, 2013) (Dugdhe et al., 2016). The proper waste management system is a must for the hygienic society in general and for a better world as a whole.

In order to protect human health and the environment from the potential hazards of delayed waste disposal and environmental pollution a systematically supervised and controlled handling of these wastes is of essence (Bashir & Banday, 2013).

The work proposed in this study illustrates how the Litter-Bin solution empowers cleaning operators to monitor in-house waste bins in real time. Thus, the system is able to help in increasing overall productivity and cleanliness.

1.2 WASTE MANAGEMENT IN NAIROBI

Solid wastes in Nairobi are a by-product of a broad spectrum of industrial, service and manufacturing processes. Primary high-volume generators of industrial solid wastes include the chemical, petroleum, metals, paper, leather, textile, wood and transportation industries. Secondary smaller generators include auto and equipment repair shops, electroplaters, construction firms, dry cleaners and pesticide applicators. Mismanagement of these wastes typically results in pollution of the natural environment and may pose substantial danger to public health and welfare.

1.3 DOMESTIC AND CORPORATE INDUSTRIAL WASTE COLLECTION

Domestic waste is also referred to as garbage, refuse or in-house waste. It consists mainly of biodegradable waste which is food and kitchen waste, green waste paper and non-biodegradable such as plastics, glass bottles, cans, metals and wrapping materials. The composition of the domestic waste streams is a function of income, consumption patterns and recycling opportunities. Nationally domestic waste is not adequately managed and is disposed at disposal sites

with minimal sorting / segregation (National Environment Management Authority, 2014).

1.4 PROBLEM STATEMENT

Litter bins are emptied at certain intervals by cleaners. This method has several drawbacks such as: Some litter bins fill up much faster than the rate of emptying and they are full before the next scheduled time for collection. This leads to overflowing of rubbish bin and poses hygiene risks. Also there are special periods (e.g. festivals, during office activities, and active company/office periods) when certain litter bins fill up very quickly and there is a need for increased collection intervals (Folianto, Low, & Yeow, 2015). Additionally, some waste bins produce uncomfortable smell composed of toxic gases which poses a health hazard to human habitation. A lot of research has been done on different aspect of solid waste management, but a few works have been done on in-house bin monitoring (Dugdhe et al., 2016).

This research proposes a prototype solution that empowers waste monitoring personnel to timely collection of waste by notifying when the fill-level or safe gas emission levels are surpassed. The proposed solution is able to help in increasing overall productivity by ensuring collections occur only when needed, over-filling is eliminated, collection costs are reduced and residents enjoy an eco-friendly waste monitoring solution.

1.5 RESEARCH OBJECTIVES

The main objective of the study is to develop a smart-bin management and monitoring prototype to proactively detect fill-level or gas emission levels and notify the relevant waste monitoring personnel. The following specific objectives have been formulated:

- i. To Identify Elements relating to bin status monitoring.
- ii To Review the approach used in in – house waste monitoring systems.

- iii To Develop a robust prototype to detect when litter bins fill up or generate toxic gases and notify the relevant waste monitoring personnel for collection.
- iv To Test the prototype

1.6 RESEARCH QUESTION

- i. What are the elements used for waste bin status monitoring?
- ii What are the approaches used in in – house waste bin monitoring systems?
- iii How can a prototype for detecting litter – bins filling up or generating foul smell and notifying relevant parties be developed?

1.7 JUSTIFICATION

This study helps to identify the gaps in monitoring of in house waste bins. The study aims at developing a prototype to benefit the domestic household and corporate user to be able to monitor the gas emission levels, and the fill levels from the waste bins.

The results of the study might propel the usage of the proposed prototype for detecting fill-level and gas emission level from waste bins and informing the waste monitoring personnel hence ensuring a safer, cleaner environment for all.

The research would also be important to scholars, as an addition to the existing body of knowledge also complementing the previous research carried out on the same. It will provide a fair platform for further research to be carried out on the adoption of waste bin monitoring systems.

1.8 SCOPE

The study is aimed at formulating a prototype for the adoption of waste bin monitoring systems. This is because such a solution may go a long way in enhancing accountability, proactive responsiveness and better management of waste, thus ensuring a safer, cleaner environment for everyone. This study was carried out in 2017.

The target of this study is the domestic household and corporate user. The prototype developed from this study will empower the domestic and

corporate user to be able to monitor the household bin status (Gas emission levels, and the fill levels) over a period of time, being able to send notifications when bins require to be attended and reports on average household waste reporting.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This section presents a review of literature on waste monitoring in order to identify the variables to consider in household waste monitoring systems, identify gaps in existing literature develop theoretical and conceptual frame work and lay a foundation for empirical analysis. The result of the study from the information will be used to provide additional value or reference of the research which will be used for the conducted research and developing the prototype.

2.2 ELEMENTS OF WASTE MONITORING SYSTEMS

A typical waste monitoring system in a low or middle – income country can be described by the below elements (Zurbrugg.2003).

- i Household was generation and storage.
- ii Reuse and recycling on household level (includes animal feed and composting).
- iii Primary waste collection and transport to transfer station or community bin.
- iv Management of the transfer station or community bin.
- v Secondary collection and transport to the waste disposal site
- vi Waste disposal in landfills.

2.3 WASTE COMPOSITION

Wealth status and consumer patterns significantly influence waste composition. A higher content of biodegradable and inert mater, results in high waste density (weight to volume ratio) and high moisture and gas content. Table

2.1 shows an extract of household composition

TABLE 2.1: Waste Characterization at Immediate Source and at Communal Collection Point

Waste Type	Composition (%)	
	At immediate Source (directly from Households)	At Communal Waste Collection Points located in Residential areas
Organic/Biodegradable	58.6	46.1
Paper	11.9	8.9
Plastics	15.9	15.4
Glass	1.9	5.6
Metal	2.0	2.3
Other	9.7	21.7
TOTALS	100%	100%

These physical characteristics significantly influence the feasibility of certain collection options. Systems operating with low-density wastes such as in industrialized countries will not be suitable or reliable under such conditions. Additionally to the extra weight, abrasiveness of the inert matter such as sand and metals, and the corrosiveness caused by the high water content, may cause rapid deterioration of the waste matter.

2.4 EXISTING ASPECTS FOR MONITORING AND EVALUATION

2.4.1 Weighing of Waste

A weight scale is installed in the waste collection vehicle in order to record the weight of all dry waste collected. A tag with a unique code is placed on each waste bin and waste from each recycling bin was recorded separately. Weights were registered on every occasion that the bins were emptied during the study period importantly, the weight of the collection bin itself is subtracted from the result. In cases where tags were missing or weights not recorded for other reasons, a default weight was calculated based on other waste containers from

the same fraction and collection date. The default weight is sometimes used for further calculation of the waste disposal intensity of the study area.

2.4.2. Waste Composition Analyses of Dry Recyclables, Food and ResidualWaste

Analyses are conducted on four occasions to investigate possible seasonal changes in waste generation and composition. Samples used for waste composition analyses were collected from three different recycling sites. All waste deposited in bins for dry recyclables and food waste and half of the vessels for residual waste (randomly selected) are analyzed. This approach is recommended by the SWA tool (Olsson, Lymberis, & Whitehouse, 2004) and the method is described in detail by (Dahlén & Lagerkvist, 2008). Consequently, errors related to sub-sampling were eliminated for dry recyclables and food waste and strongly reduced in the case of residual waste. Source-separated hazardous waste, WEEE, batteries and bulky waste are not considered in these analyses.

The same method of waste composition analysis was used on all four occasions. It is based on (Battese, 1995) and developed in co-operation with Lulea University of Technology

2.4.3 Waste Composition Analyses Of Bulky Waste, Hazardous Waste andWEEE

In the case of bulky waste (including bulky WEEE, metal and other bulky waste disposed of in mobile containers), source-separated WEEE and source-separated hazardous waste, the total weight delivered to the waste treatment facility is recorded. The weight of all non-source-separated bulky waste dumped in the area and collected by facility managers was also recorded.

2.4.4. Indicators For Evaluation

Four indicators were used to evaluate the current waste disposal system at the study site. All parameters were calculated on a wet weight basis. The specific waste generation (kg household per year) was determined based on a weekly average derived from 104 weeks weighing of waste. Data are presented as a total and for all source-separated fractions and residual waste. The source-sorting ratio (weight-%) defined as the weight of collected source-sorted recyclable material in relation to the sum of the same material – sorted, incorrectly sorted and unsorted. Ratio of miss-sorted waste (weight-%), defined as the mass of non-packaging, non-newspaper and non-food waste deposited in bins designated for the same fractions, in relation to the total amount of disposed waste in each particular fraction.

Ratio of source-separated similar materials (weight-%), defined as the mass of non-packaging materials made from plastic, metal and paper (e.g. plastic sieves, metal bookstands and books not covered by the Producer Responsibility Ordinance or included in the source-separation instructions distributed to households regarding food waste) disposed of in bins designated for dry recyclables, in relation to the total amount of miss-sorted waste in the particular fraction.

2.5 INTEGRATED TECHNOLOGIES AND APPROACHES

2.5.1 Wireless Sensor Network (WSN)

A wireless sensor network is designated as a network of spatially distributed and devoted sensor nodes that cooperatively sense and record the physical conditions of the target area or object and disseminate the collected data to a base station. It can control the target object or environment by facilitating interaction between persons or computers and the area of interest. The sensor node contains radio transceiver, microcontroller, sensor board, and energy source, usually a battery. The main constraints that must be addressed when designing a WSN are the node's energy consumption, computational speed rate, bandwidth, and memory. Though, WSNs were primarily designed to assist military operations,

since the start of the third Millennium its application has been extended to different areas which creates a growing interest from industrial and research perspectives. In the last few years WSN is used in a huge number of applications like habitat monitoring, building automation, smart energy, health care, water and air quality monitoring, construction health monitoring, agriculture and food industry, fire detection etc (M.A. Al Mamun, Hannan, Islam, Hussain, & Basri, 2015).

2.5.2 ZigBee

ZigBee is an open standard that operates based on the IEEE 802.15.4 specification and offer the network infrastructure required for wireless sensor network (M. A. Al Mamun, Hannan, Hussain, & Basri, 2013). ZigBee outlines the network and application layers of the protocol stack where 802.15.4 specify the physical and MAC layers. ZigBee has a very low duty cycle and very long primary battery life. It supports static and dynamic star and mesh networks and more than 65,000 nodes, with low latency available. The ZigBee is enhanced to build ZigBee PRO feature set that support low power consumption and large area networks (M.A. Al Mamun et al., 2015)

2.5.3 GSM/GPRS

GSM system and can be associated with the internet (A. Al Mamun, Hannan, & Global System for Mobile communications (GSM) is a standard for cellular communications developed by European Telecommunications Standards Institute. GSM offers voice telephony as its main service in which voice is encoded digitally and carried by the GSM network as a digital stream in a circuit-switched mode (Islam, Arebey, Hannan, & Basri, 2012). It also offers data services which allowed a maximum bit rate of 14.4 kbit/s and a channel is allocated to a single user for the period of the connection in circuit-switched mode. To overcome the limitations of data service, General Packet Radio Service (GPRS) is introduced which works in packet switching techniques. GPRS is developed from the existing Hussain, 2013). GPRS facilitates the users to share the network resource to several time slots simultaneously and offers a bit rate of 170kbit/s. It also offers volume based

charging to users as pay as you use (M. A. Al Mamun et al., 2015). It provides a link between mobile users and data network and provides high-speed wireless IP or X.25 services for users. GPRS uses packet switching technology and each user can take up a number of wireless channels at the same time. The same wireless channel can be shared by multiple users and then resources can be effectively used. Using GPRS technology to send and receive data packets, users can be always on line. GPRS network has a wide coverage and can truly achieve ubiquitous, real-time communication (Islam et al., 2012).

2.5.4 Radio Frequency Identification (RFID)

The RFID is an available technology since the early 1900's and was utilized during World War II. The technology uses a few simple components. The RFID tag is composed of an antenna, integrated circuit, a reader that gathers information from the ID tag, and a database system that is used to store the information gained through interrogating the ID tag. Based upon the application, the identification tag can be active or passive. RFID is designed to enable readers to capture data from tags and transmit it to a computer system without any physical connection at a range of radio frequency. The antenna uses radio frequency waves to transmit a signal that activates the transponder. RFID is getting more attention across different industries. RFID technology is used in a wide range of applications worldwide including automotive, contactless payments, laundry, library, livestock, pharmaceutical, retail supply chain management, ticketing and in industry as an alternative to the bar code (Islam et al., 2012).

2.5.5. Geographic Information System (GIS)

A Geographic Information System (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information (Maguire, 1991). GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships,

patterns, and trends in the form of maps, globes, reports, and charts. A GIS helps you answer questions and solve problems by looking at your data in a way that is quickly understood and easily shared (Islam et al., 2012; Khan & Samadder, 2014). GIS technology can be integrated into any enterprise information system framework. GIS is used to location identification of a monitoring system by mapping out the location and movement in the form of geographic map (Chalkias & Lasaridi, 2009)

2.5.6 Web Camera

A webcam is a digital camera designed to take digital photographs and transmit them over the internet (Poh, McDuff, & Picard, 2011). The camera connects to computer and takes a snapshot image that gets saved to computer's hard drive. Webcam software allows controlling how often the camera takes a photo and updates (sends) that photo on web server (Islam et al., 2012).

2.6. EXISTING MODELS/SOLUTIONS

2.6.1. Automated Solid Waste Bin Monitoring System

The designed system uses wireless sensor networks integrating two different communication technologies. A set of sensors have been used to measure the bin status. The system can respond in real time which can help to develop an efficient solid waste monitoring system to reduce the operational cost and pollutant emission as well as can keep the environment green and safe (M. A. Al Mamun et al., 2015).

A sensor node is installed in a 240L waste bin. Wasp mote from Libelium has been chosen as sensor nodes. In this mote, ATmega1281 microcontroller is used and it consumes 15mA power in active mode and 55uA power in sleep mode. It also contains a built-in accelerometer sensor. XBee-ZB-PRO RF module from Digi has been used as the radio transceivers which conform to ZigBee-PRO v2007 standard. ZigBee-PRO make best use of all the capabilities of the ZigBee feature set which is built on the top of the IEEE 802.15.4 functionalities and it enables support for larger networks

encompassed of thousands of nodes. For the sensor set, the ultrasonic XL- MaxSonar-WRA1 (MB7070) from Maxbotix is used to measure the waste filling level, the AMS Load Cell resistance sensor form Hanyu is used to measure the weight of waste inside the bin, PLA41201 hall effect sensor is used to track the

State of the bin cover and to measure the temperature and humidity MCP9700A and 808H5V5 sensors is used accordingly. To integrate the sensors in the mote, the Smart Metering v2.0 board from Libelium is used. See figure 2.1.

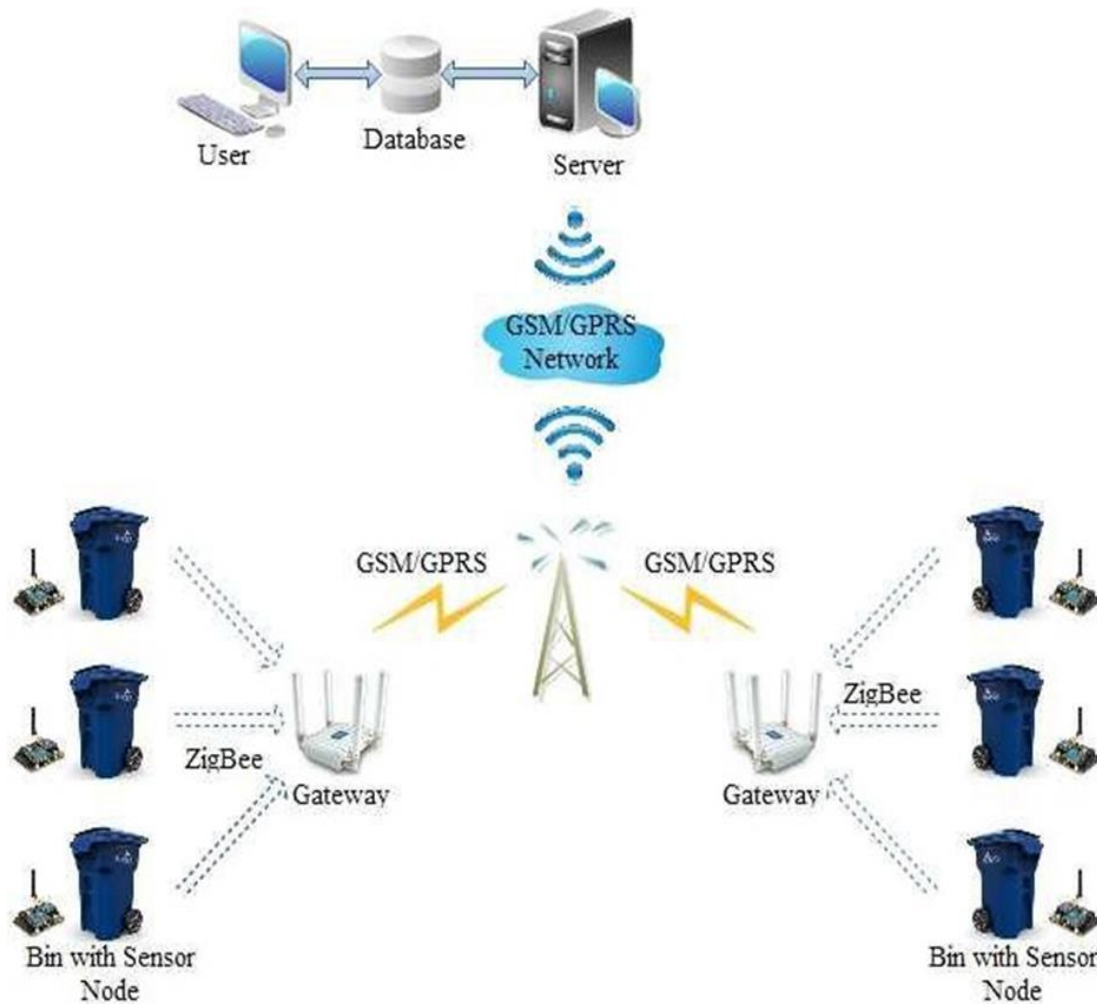


Fig: 2.1: Automated Solid Waste Bin Monitoring System Framework

2.6.2. Smart Dustbin-An Efficient Garbage Monitoring System

In this study, GSM 900A modem is used to send the messages. It consists of a GSM/GPRS modem with standard communication interfaces like RS-232 (Serial Port), USB, so that it can be easily connected to the other devices. The ultrasonic sensor is used to find the height of garbage filled at different intervals of time. However, three sensors can be employed at various heights like $h/3$, $2h/3$ and h , where h is the height of the bin but to make it affordable and to achieve the same results, only one sensor is placed at surface level. Arduino Uno board is used as microcontroller platform. Interfacing is done between GSM modem and Arduino board by connecting RX pin of modem to TX pin of board and vice versa. ECHO and TRIGGER pins of sensor is connected to digital pins 5 and 13 of Arduino board. Arduino board works at 5V power supply and GSM modem requires 2A to power on. The threshold height is set to 10cm. Threshold distance is the difference in height at which sensor is placed and the level of garbage fill. During the course of garbage accumulation, whenever the difference falls below threshold value, GSM modem is activated to send an alert signal to the concerned authority through an SMS (Monika, Rao, Prapulla, & Shobha, 2016). Fig 2.2 represents a block diagram of the architecture.

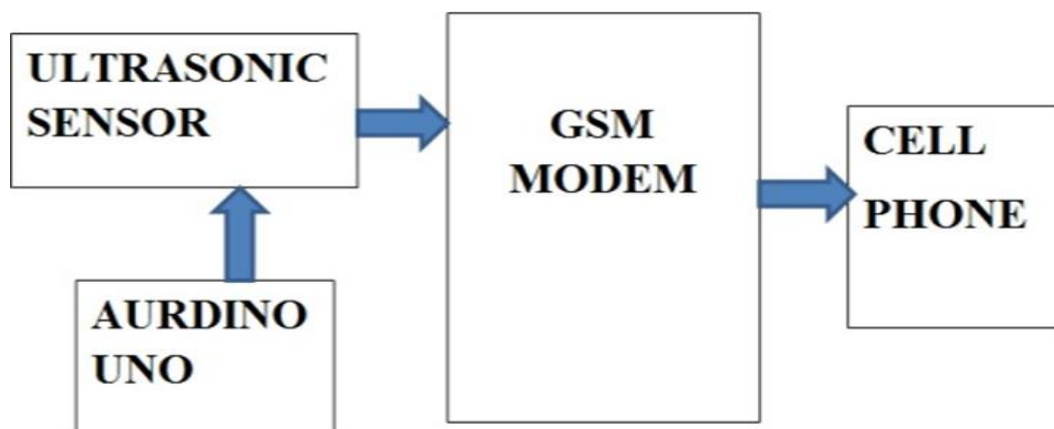


Fig: 2.2: Block Diagram for Smart Dustbin-An Efficient Garbage Monitoring System

The shortcoming of this system is that, there is no provision for smart monitoring of the bins status from a centralized system for proper monitoring. Secondly, the solution only caters for monitoring one aspect of the bin status, being fill-level only. There is a need for monitoring other aspects including the weight and Gas emission levels.

2.6.3. Smart and Wireless Waste Management

A set of three ultrasonic sensors as level sensor are installed at top portion of the bin. Along with it there will be load cells for pressure measurement purpose. Ultrasonic sensors will be interfaced with ultrasonic signal conditioning chip. Whereas the signal from array of 4 load cells will be given to Analog to Digital Converter. A GPS module will be installed outside the bin. Microcontroller will receive inputs. It will perform signal processing as per signal processing algorithms. With the help of an electronic switch and timing circuit in microcontroller the voltage of battery of sensors will be controlled. Microcontroller will communicate to GSM modem through UART. GSM modem will send the SMS to the municipality head office. So they will get SMS before their periodic interval visit of picking up dustbin. Fig 2.3 illustrates the systems block diagram architecture.

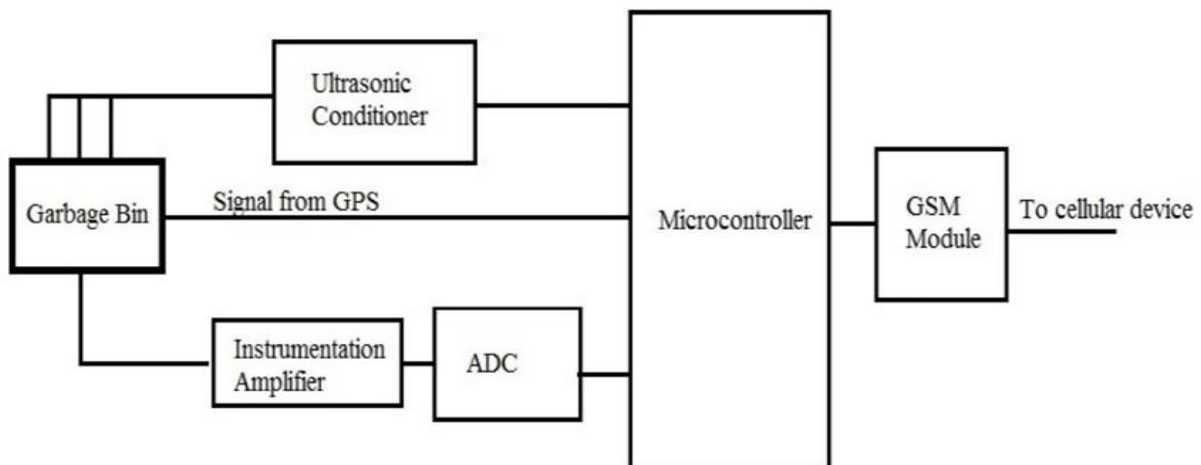


Fig: 2.3: Block diagram for Smart Garbage Bin

2.7 SOILED WASTE MANAGEMENT CHALLENGES

The urban councils are responsible for the implementation of these instruments including ordinances and bye-laws. Environmental policymaking remains largely a function of the central government, but implementation of policies and legislation is devolved to the Local Governments (Liyala 2011; Oberlin 2011; Okot-Okumu & Nyenje 2011; Tukahirwa 2011).

The existing laws on waste management are not being effectively enforced (Liyala 2011; Oberlin 2011; Okot-Okumu & Nyenje 2011; Simon 2007), which may be attributed to inherent weaknesses of the laws themselves. The informal sector and the community therefore operate with little or no regulation at all.

Waste management is poorly financed because it is not a prioritised activity in all urban councils. Funds for the operation of the urban councils are mainly from external sources (over 50 %) like the central government and donors in the form of grants (Liyala, 2011). This means fiscal autonomy has not been realised by the EAC urban councils as observed by Okot-Okumu & Nyenje (2011).

Households not served by waste collection have developed their own waste management systems. The most common household waste management methods identified are waste burning and backyard burying or indiscriminate open dumping (Liyala 2011; Oberlin, 2011; Okot-Okumu & Nyenje 2011; Simon, 2007). Waste composting is still small-scale and insignificant, often by households and mostly for individual household gardens, while Composting, which is technically viable, to be strongly vulnerable to external factors (Oberlin & Sza'nto', 2011). In East Africa these innovative methods for waste management remain un-researched denying interested individuals among the urban communities information on such projects.

Little investment has been made in MSWM research, resources and human capacity development. The only coordinated major research that has been done on

waste management in EA cities is the one under PROVIDE where some of the MSc and PhD research results have already been published (Liyala 2011; Oberlin 2011; Simon 2007).

Even though urban councils contract private operators to collect wastes, the urban councils themselves are still the main waste collectors and the combined efforts of the urban councils with the private sector have not yielded the levels of success expected. This is evident by the common scenes of uncollected wastes on roadsides and in drainage channels, streams and wetlands in urban and peri-urban areas.

The problem of MSWM in East Africa is compounded by the rapid urban population growth caused by rural to urban migration overstressing resources. The rising urban population and increasing industrial activities means larger volumes of wastes that pose threat to public health and the environment since they are predominantly decomposable organic and E-wastes are also increasing in the wastestream. Zurbrugg (1999) noted that the problems of MSWM are of immediate importance in many urban areas of the developing world and waste management is known as one of the key issues in urban management aside from water and sanitation. Municipal wastes therefore constitute one of the most crucial health and environmental problem of African urban councils (Achankeng 2003; Adebilu & Okekunle 1989; Asomani-Boateng & Haight 1999; Kaseva & Mbuligwe 2005). It is evident from Kaseva & Mbuligwe (2005) for Tanzania, Rotich et al., (2006) for Kenya and Okot-Okumu & Nyenje (2011) for Uganda that urban areas in East Africa have been experiencing serious solid waste management failures.

The prevailing attitude of the public towards waste collection and disposal or treatment is poor (Liyala 2011; Oberlin 2011). The urban communities generally do not participate in waste management responsibly. The combination of all these factors together with the urban council weaknesses that cause management failures have led to the accumulation of wastes in neighborhoods leading to

environmental degradation and threat of disease epidemics such as cholera, diarrhea and parasites. Socio-cultural and attitude problems in waste management may be addressed gradually through public education to sensitize the communities, while economic issues can be addressed by providing livelihood opportunities (employment) within the waste management activities.

2.8. CONCEPTUAL MODEL

The prototype consists of an Arduino ATmega328P Microcontroller used to interface the sensor system and the Azure cloud. Dustbins in an area are embedded with low power and low cost smart ultrasonic and gas sensors that are connected to the cloud, which acts as a central hub for all bins. The bins transmit their gas content and its fill-level status to the central cloud platform. The cloud platform further pushes the data to the client app a GUI (Web or mobile) in which the current gas content and their state (filled or not) is displayed. Database maintained at the central server can be used to generate the monthly or yearly reports regarding amount of waste collected in a week, month or year. This data can be used for management purposes. This prototype is aimed at ensuring collections occur only when needed, Over-filling is eliminated, reduced collection costs, reduced harmful gas levels and residents enjoy a friendly waste management service. Figure 2.4 illustrates the conceptual design.

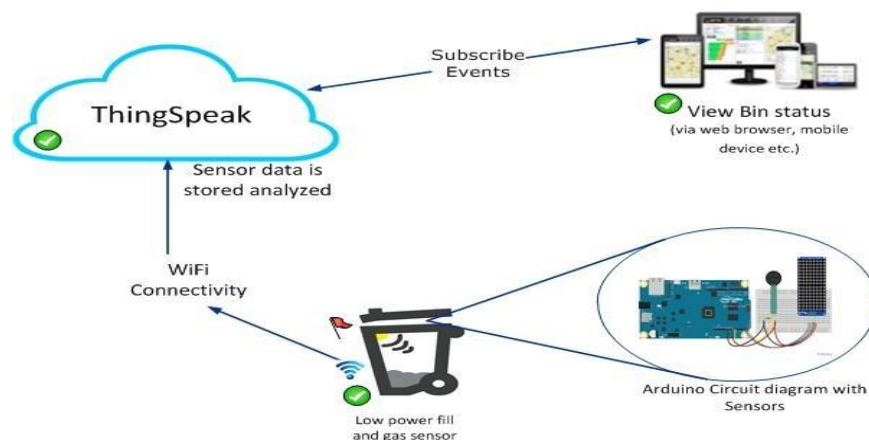


Fig: 2.4: Conceptual model Diagram

CHAPTER 3

AIM AND SCOPE

3.1. AIM

- Monitoring and disinfection system used for COVID isolation wards and in hospitals.
- Minimize the risk of contamination to the cleanliness workers and other health workers from harmful viruses and other pathogen.
- Monitoring the level of garbage in the bin and level of toxicity.
- Use of renewable source of energy for working.
- Safe disposal of healthcare waste to avoid further spread of viruses

3.2. SCOPE

- Efficient waste management and bin level monitoring.
- The alert and notification system.
- UV disinfection system.
- Compact and durable.
- Smart Analytics

CHAPTER 4

MATERIALS AND METHODS

4.1. SYSTEM ANALYSIS AND DESIGN

4.1.1. Introduction

In order to analyze the collected data and guarantee consistency and completeness, the research employed the use of Google Docs and Microsoft excels spreadsheets for quantitative data analysis. The completed questionnaires and data gathered from personal interviews were first encoded in an analyzable format, and then analyzed, and lastly presented in a tabulated and summarized way using tables, bar graphs and pie charts. These methodologies provided suitable presentable designs for a general feel of the outcomes.

The study also employed a multiple technique methodology of obtaining requirements from possible clients. The requirements elicitation process was achieved by administering questionnaires and building of prototypes. This combination enabled the researcher acquire a complete picture from the diverse sets of clients and stakeholders.

4.1.2. Outcomes

The researcher ensured research validity by ensuring that the data collected from the survey respondents was relevant to the study. Also, validity was ensured by subjecting the questionnaires to experts, with the guidance of the University supervisor.

4.1.2.1 Trash bins monitoring ability

As illustrated in figure 4.1 below, 27% of the sample size responded that it was extremely hard for household users to be able to detect pungent smell and fill ups of

in-house trash bins. Additional 21% said that it was Hard, 25% were neutral, 9% said it was easy and another 18% responded that it was extremely easy.

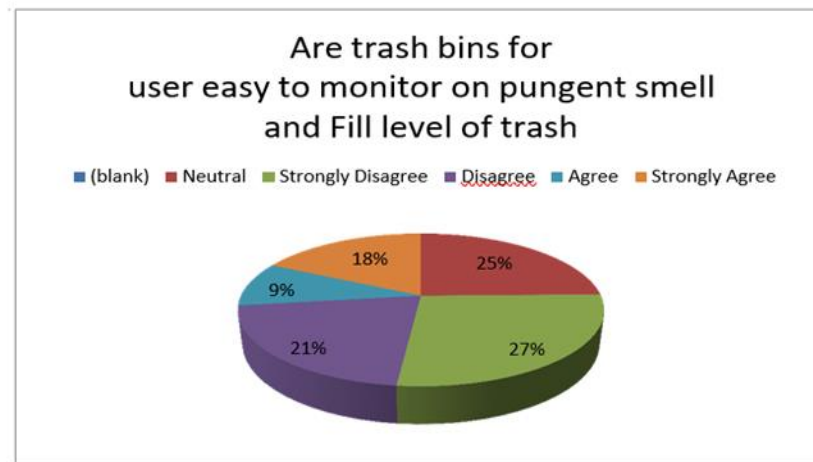


Fig: 4.1: Ease of monitoring Bin Status

4.1.2.2 Efficiency of Current Bin Monitoring

The Survey as from figure 4.2 indicated that 31% Majority of the sample responded that the Current method is not efficient. An additional 12% stated that it was extremely in-efficient. 19% of the population was neutral, 31% responded that it was effective and 8% that it was extremely efficient.

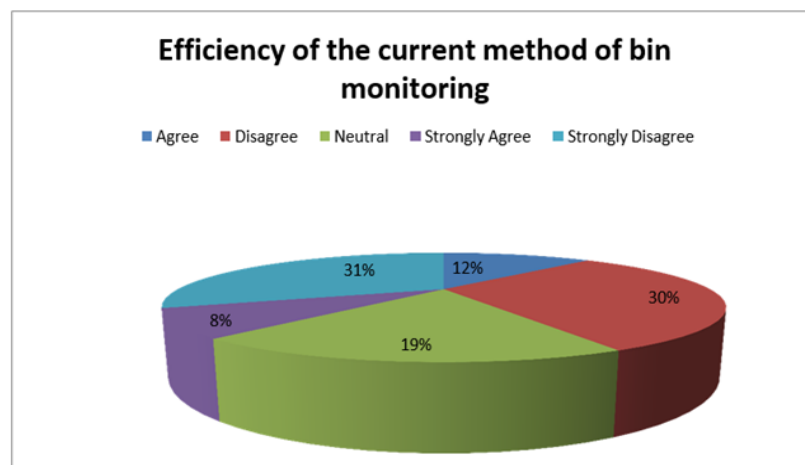


Fig: 4.2: Efficiency of current Bin Monitoring

4.1.2.3 System Alerts Capability

From the Efficiency survey from figure 4.3, the greater majority of 57% responded that the current system is completely incapable of alerting users in case bin emits gas or is filling up. An additional 12% stated the current method is incapable, 7% of the sample were neutral, 12% responded that it is capable and another 12% stated that it is highly capable.

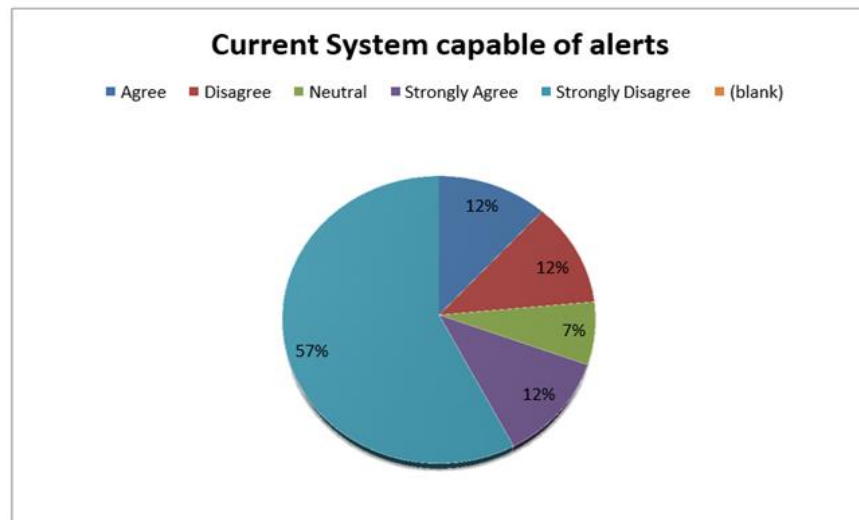


Fig: 4.3: Capability of alerts

4.1.2.4 Reporting and Dashboard Capability

As from the results on figure 4.4, 61% of the sample strongly disagreed that the current methods have reporting capabilities. An additional 19% also disagreed. 7% were neutral, 7% agreed and 6% strongly agreed on this capability.

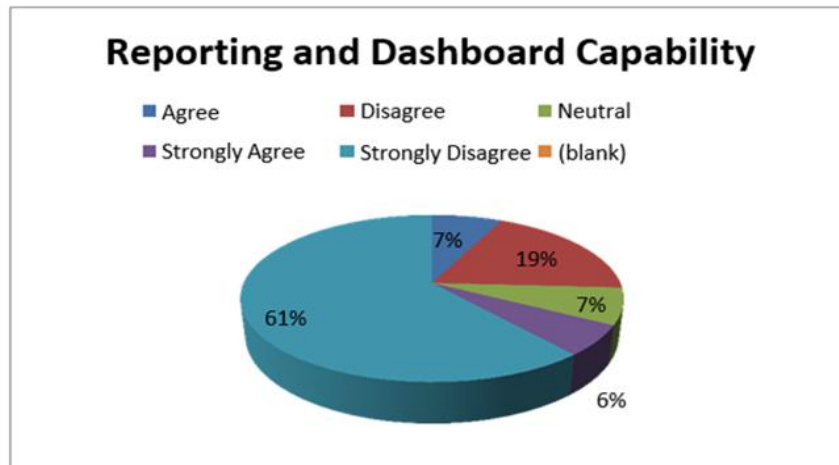


Fig: 4.4: Reporting and Dashboard capability

4.2. SYSTEM REQUIREMENTS

From the User requirements study carried out in this study, the researcher was able to identify the gaps and user needs that formed the basis for the below identified user and system requirements

4.2.1 User Requirements

- A system that would be able to monitor on Gas emission, and Fill level in the shortest time possible.
- A system that would notify or present this information to the relevant people.
- A user friendly and interactive system.
- A secure system with access restrictions and privacy.
- A system that can provide historical usage reporting.

Several functional, non-functional and technical requirements emerged from the analysis of data obtained in this research study. These requirements informed the architectural design and the various components crucial for the Smart-Bin solution to solve the research problem.

4.3. FUNCTIONAL REQUIREMENTS

These are the core system requirements the system must fulfill in order to be regarded as having solved the research problem. They include:

4.3.1 *Setting Optimal Fill Level*

This allows for the system user/operator to specify the fill level they consider optimal, after which exceeding this limit will result in notifications/ alerts for collection.

4.3.2. *Set Optimal Gas-Content Level*

This allows for the system user/operator to specify the gas content level they consider optimal, after which exceeding this limit will result in notifications/ alerts for collection.

4.3.3 *Check Bin Status*

This allows the user to view at any time, the gas, fill-level of the monitored bin via a web or mobile phone browser.

4.3.4 *Notifications*

This feature will allow the home user to be able to be notified whenever the fill-level or gas content level surpasses the stated optimal levels.

4.3.5 *Reporting*

This feature allows the system to generate reports when required.

4.4. PROPOSED SYSTEM

The project Dr. Dispose is a monitoring and disinfection system which is designed for COVID isolation wards inside the hospitals. Dr. Dispose Bins minimize the risk of contamination to the cleanliness staff and other health workers from coronavirus spread and the proper management of COVID-waste is done by easily monitoring the bins levels inside the hospital. This system adds few sensors that provides much more information about garbage present in garbage bins inside the hospital ward.

This system also provides information about the gases produced by these garbage over time and their level of toxicity. Using these information garbage collection schedule to reduce the risk any disease spreading. When garbage container has reached its maximum capacity it automatically send alerts and the LCD screen which is placed on the entrance of ward is used to display the status of the level of garbage collected in the bins when it is full or overstuffed. It has ultraviolet (UV) lights which can neutralize the virus and other pathogens. Also it has open and close lid to prevent further contamination through bugs and flies. The system is powered by a long lasting rechargeable battery which gets charged alternatively by the source of solar panel on top of lid and Piezoelectric crystals on foot pedal.

4.4.1 Sensing Module

In this system, there are a number sensors which are used to provide different vital information about the garbage. Firstly we have the ultrasonic sensor, which is used to monitor the level of garbage actively. And next up we have the gas sensor, which is used identify the level of toxicity of the gases produced by the stored garbage.

4.4.2 Data Traffic and Transfer Module

This module mainly consists of single micro controller unit called the ATmega328. It is a device based on the 12E version of ESP-8266 micro controller which is used to oversee the incoming data traffic from the suite of sensors present

and pass it on the wifi chip. The communication is carried between the garbage bin and user's BLYNK app using the above mentioned wifi chip.

4.4.3 Smart Induction UV Disinfection System

Based on the available scientific evidence that UV light can destroy various viruses, it's probably true that UV light can kill SARS-CoV-2. UV light can damage your skin, so you shouldn't get exposed to it. So smart induction system is built inside the bin using UV light. A timer circuit which detects the door closure and switches on the UV-C lamp after a delay of 3–10 s was also provided.

4.4.4 Blynk Module

This module works in the background of this active garbage management system to constantly update the user about garbage collected. BLYNK app actively provides with latest information about the garbage bins to the user. This run using the predefined principles set by the developer. It contains LCD's Screen or display outside the ward which shows level of waste in the bin to alert the user in time.

4.4.5 Solar Piezo Hybrid Power Charging System

The use of renewable resources like the solar energy and various other clean sources of energy has been on an increase in demand in the recent years due to their ease in availability and low and cost. Here we use the solar panels and the Piezo electric Transducers combined to give an electric charge.

4.5. COMPONENTS USED

4.5.1 Atmega 328 Controller

The ATmega328 Controller is an open-source controller board based on the Arduino.cc ATmega328 microchip controller. The ATmega328P is a high performance yet low power consumption 8-bit AVR microcontroller. The board is equipped with sets of digital and analog input / output (I/O) pins that can be interfaced with different

boards (shields) for expansion and other circuits. The ATmega328 comes pre-programmed with a boot loader that enables new code to be uploaded to it without using an external hardware programmer.

4.5.2 Ultrasonic Sensor

The Ultrasonic sensor is used for calculating the level of garbage filled in the bin. There are two opening in the sensor. One transmits the ultrasonic waves and the other one receives the wave. The wave emitted by the sensor travels in air and when it hits any material, it gets reflected back toward the sensor. This reflected wave is observed by the receiver module and calculates the level by calculating the time taken by the wave to retransmit back at the receiver side.

4.5.3 Gas Sensor

When waste such as Hospital waste, are deposited in huge trash bins, chances of generating harmful gases are very high. Gas sensor can be used to detect combustible, flammable and toxic gases, and oxygen depletion. These sensors can detect carbon monoxide, methane, hydrogen sulfide etc. which will easily detect the toxicity of the garbage.

4.5.4 Wi-Fi Module (Esp8266)

The ESP8266 Wi-Fi Module is a self-contained SOC with built-in TCP / IP protocol stack that can provide connectivity to your Wi-Fi network to any microcontroller. The ESP8266 will host an application or discharge all Wi-Fi networking functions from another device processor. The ESP8266 Wi-Fi module is a low cost component with which manufacturers make module microcontroller wirelessly networkable. This is the most critical component in the system because it conducts the IOT operation.

4.5.5 *Arduino IDE*

Arduino IDE is an open source Arduino software used to code the micro controller and upload it on board. It works in all Windows, Mac OS and LINUX.

4.5.6 *Blynk App*

It is an android app that allows communication which allows its communication with Wi-Fi compatible micro-controllers.

4.5.7 *Jumper Wires*

These are tiny wires which connect different micro-controllers and sensors together.

4.5.8 *Liquid Crystal Display (LCD)*

The word LCD stands for liquid crystal display. It is one type of electronic display module used in a wide range of applications such as various circuits & devices such as cell phones, calculators, computers, television sets, etc.

4.5.9 *UV Lamp Disinfection*

UV light strips is effective in disinfection of air, water etc. and is good for disinfecting surface. However the disadvantages are it can lead to skin cancer due to long term exposure. When the lid opens for collecting the waste the UV light gets OFF and undergoes disinfection after closing the lid.

4.5.10 *Solar Cell Panel and Piezo Electric Transducer*

Small 10 cm solar cell panel which is readily available in the market has been used along with the few Piezo electric transducer.

4.6. CONSTRUCTION OF PROTOTYPE

The prototype is constructed as follows: Taking a plastic container or a dustbin, placing an ultrasonic sensor at the front part of the dustbin. The lid of the dustbin is taken as a cardboard and a servo motor is placed on the lid. Another ultrasonic sensor is placed inside the dustbin. The code of this project is divided into two parts. The first part code indicates the working of the dustbin i.e. mainly opening the lid of the dustbin. The second part code indicates the notification part which is received on the mobile using the Blynk app.

The first part is constructed as follows: The ultrasonic sensor placed at the front part has four pins named Vcc, GND, ECHO and TRIG. The pin TRIG, pin ECHO is connected to digital pin numbers two and three on the Arduino Board. The servo motor has three pins named Vcc, GND, and servo pin. The servo pin of Servo motor is connected to digital pin number nine on the Arduino board. The Vcc of ultrasonic sensor is connected to 5V of Arduino board and the Vcc of servo motor is connected to 3.3V of Arduino board. The GND pins are connected to ground on the Arduino board. After the connections are made, the Arduino is connected to the system and using the Arduino IDE the code is dumped inside the Arduino. This ends the connection and code dump for the first part.

The second part is constructed as follows: The ultrasonic sensor which is placed inside the dustbin also has the same four pins named Vcc, GND, ECHO and TRIG. In the Arduino IDE the board has to be changed from Arduino UNO to NodeMCU, if the board is not available in the list then we need to install the board from the Boards Manager. In this part the TRIG and ECHO pins of ultrasonic sensor is connected to digital pins D5 and D6 of NodeMCU. The Vcc is connected to Vin of NodeMCU and GND to ground of NodeMCU. This is the connection that is required and now the code should be dumped into NodeMCU. This ends the connection and code dump for the second part.



Fig: 4.5: Construction of front part of dustbin



Fig: 4.6: Construction of top part of dustbin



Fig: 4.7: Inside part of the dustbin

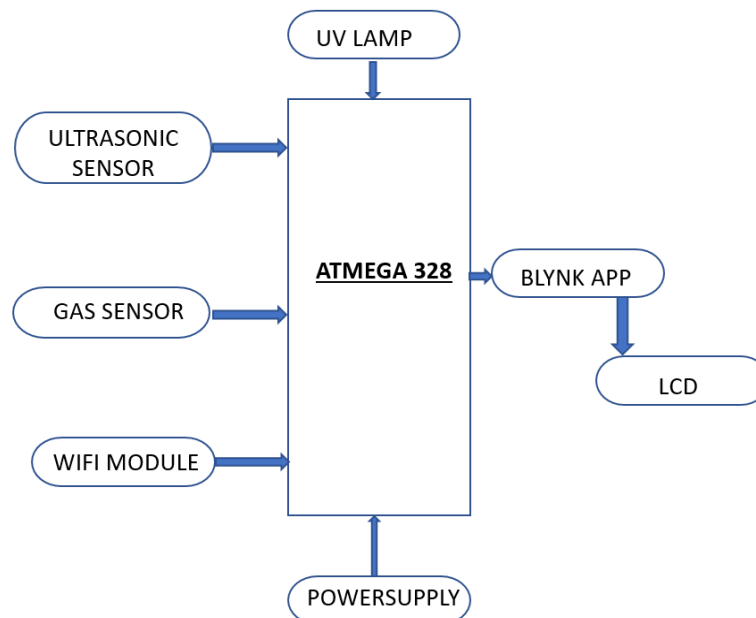


Fig: 4.9: Block Diagram of Operating System

4.7. SYSTEM ARCHITECTURE

The System Architecture can be presented in three main tiers. Presentation layer, application layer and the data layer. The presentation layer presents data to the user. In the figure 4.10 the mobile application and the web browser client interfaces presents this layer. The application layer performs the application logic. It provides a link by which the clients in the presentation layer are able to access data in the data layer. It consists of the cloud based server and the code running in the arduino microcontroller.

4.7.1 Architecture Design

The system consists of three main components, a cloud based server setup, Arduino ATmega328P Microcontroller used to interface the sensor system and the Azure cloud. Dustbins in an area are embedded with low power and low cost smart ultrasonic and gas sensors that are connected to the cloud, which acts as a central hub for all bins. The bins transmit their gas content and its fill – level status to the central cloud platform. The cloud platform further pusher the data to the client app a GUI (Web or mobile) in which the current gas content and their state (filled or not) is displayed. Database maintained at the central server can be used to generate the monthly or yearly report regarding amount of waste collected in a week, month or year. This data can be used for management purposes. See figure 4.10 for the architectural diagram.

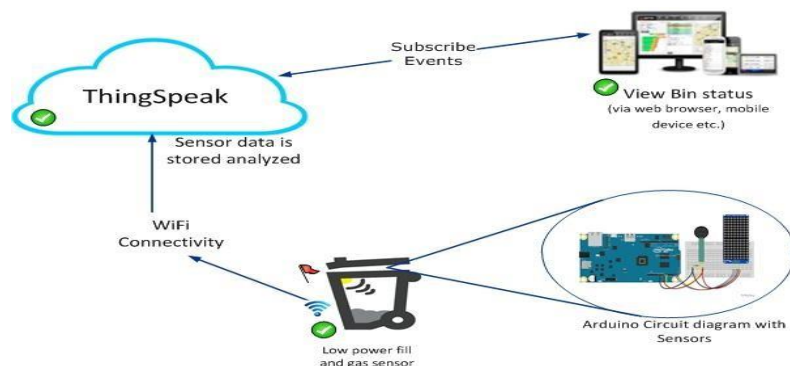


Fig: 4.10: Architecture Diagram

4.7.2 Process Workflow

The workflow design depicts the flow of data and information through the system. It caters for the logical developer design options and defines actions of given decisions and information process flows. Figure 4.11 illustrates the design achieved from the requirements of this research.

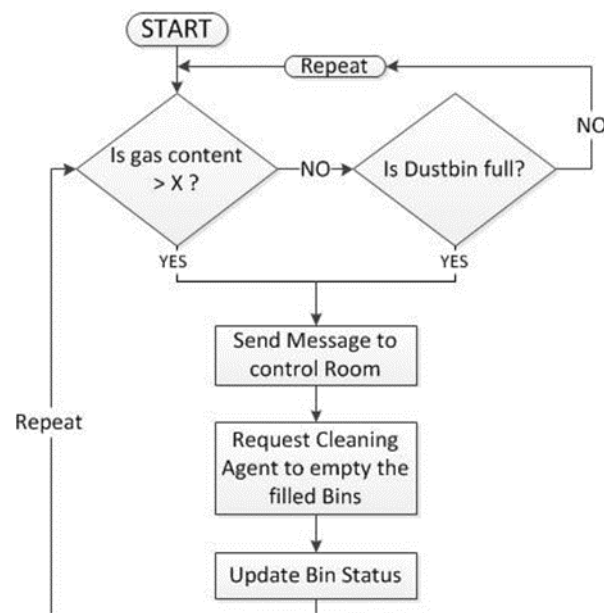


Fig: 4.11: Process workflow

4.7.3 Use Case Modeling

Figure 4.12 illustrates a smart bin use case diagram used to offer a visual representation of the various roles of the system and how they interact with the various functions of the system. It illustrates the activities performed by the users of the system that is the functional requirements from a user's perspective.

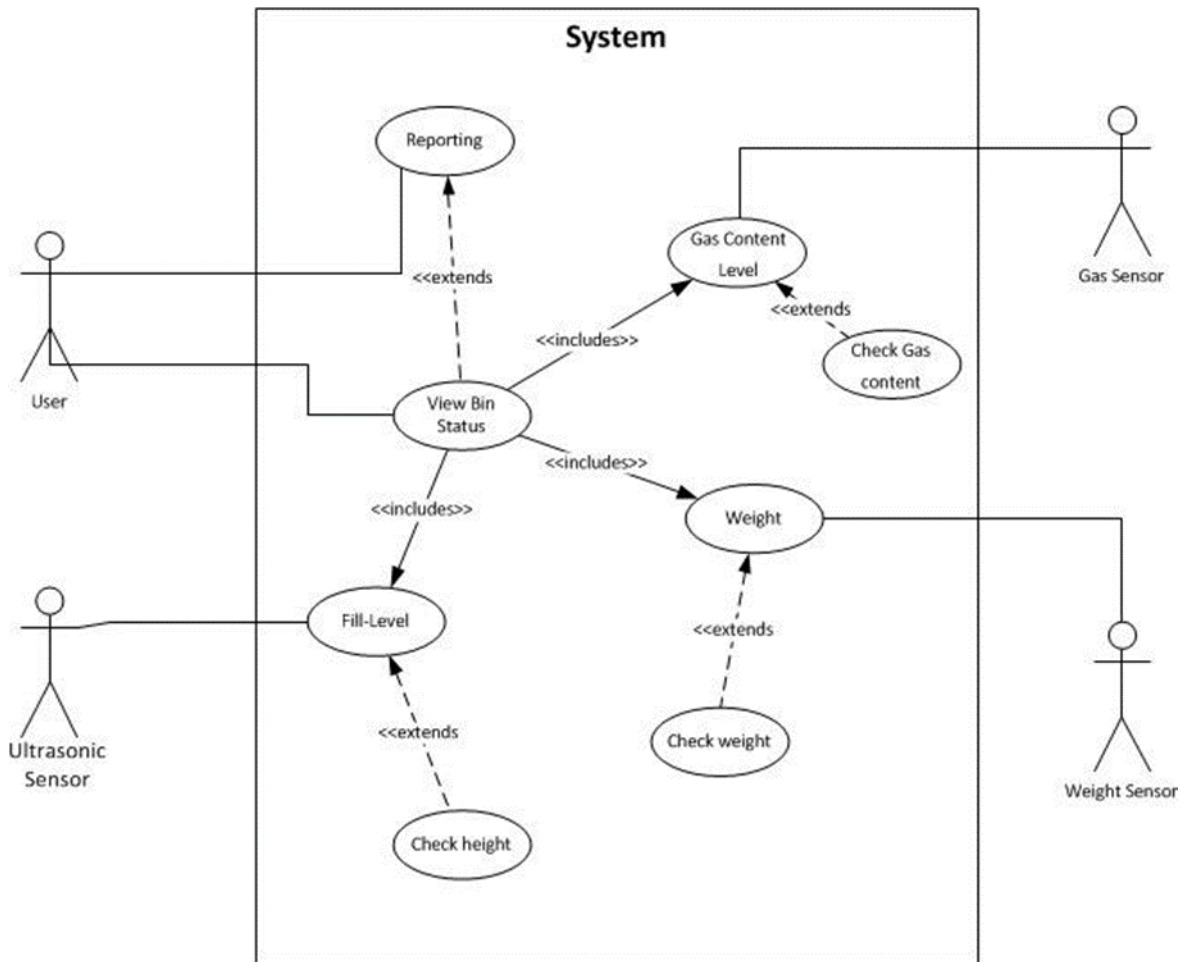


Fig: 4.12: Use Case Diagram

4.7.4 Sequence Diagrams

The sequence diagram in fig 4.13 depicts how objects interact with each other via sending and receiving of messages and responses in the execution of a use case or operation. The user has to register then login to be able to interact with the system. On successful installation and login, the user could prompt the System to display the bin status from a web browser or mobile browser. This request will prompt actions to check the gas level, and the fill level of the bin and transmit the values through the arduino microcontroller to the user's browser on his device.

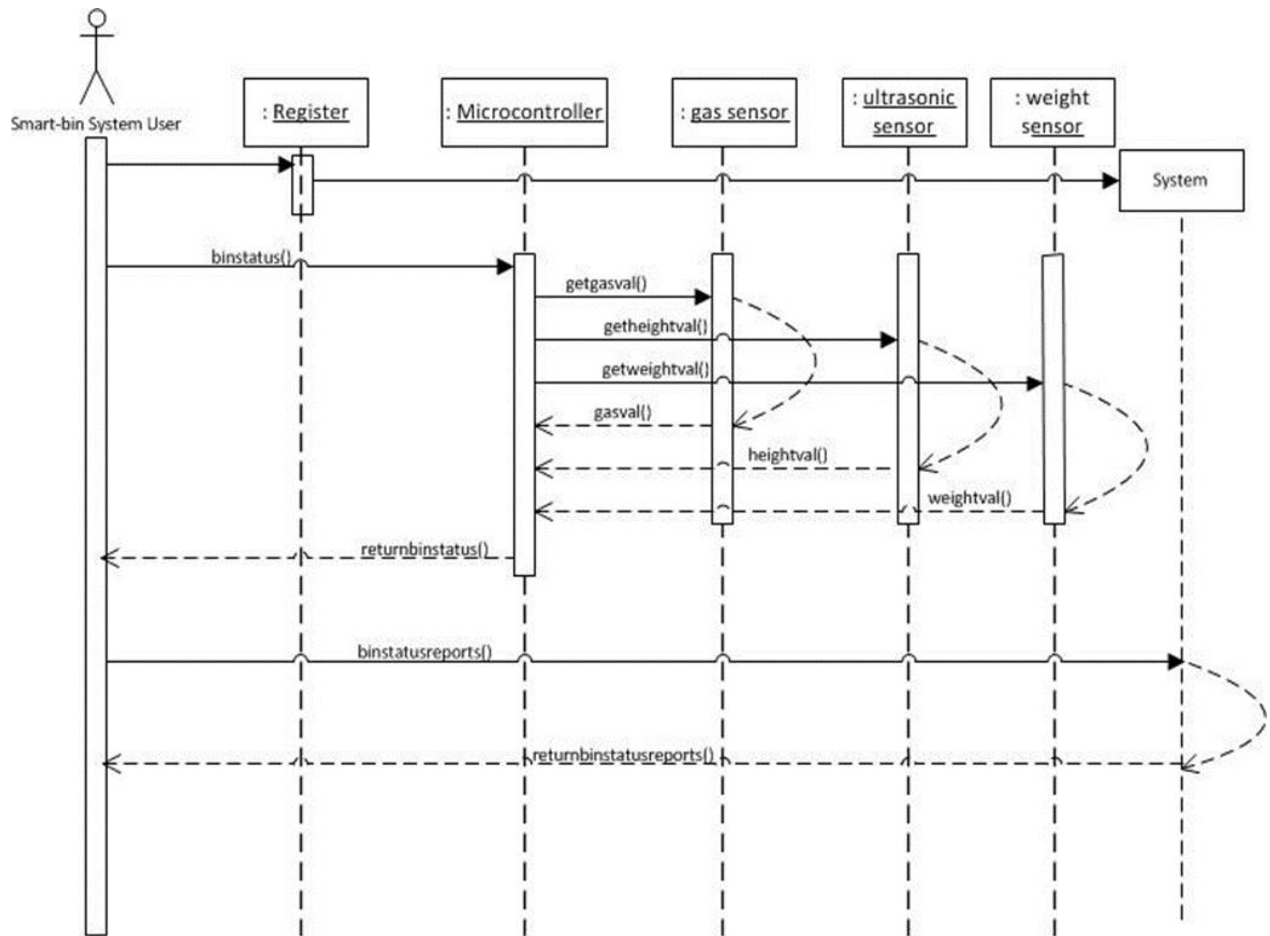


Fig: 4.13: Sequence Diagram

4.7.5 Data and Process Modeling

A Data Flow Diagram (DFD) depicts the flow of data and relationships between different components of a system. They show the high level details and how data inputs are transformed to data outputs via functional transformations. They show the functions required to run in a program and the data these functions need (Le Vie, 2000). Figure 4.14 describes in detail the system Data flow Diagram.

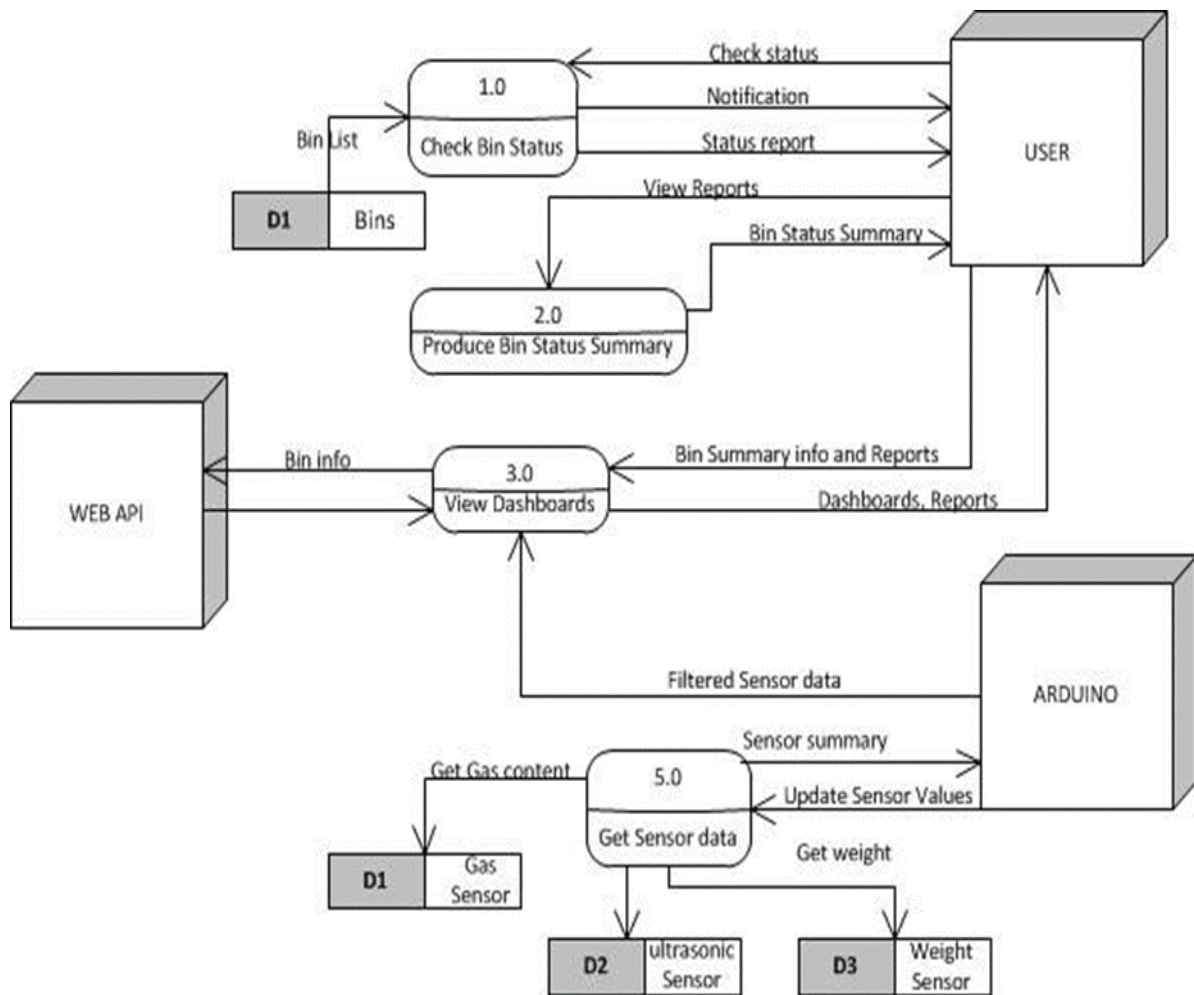


Fig: 4.14: Data flow Diagram

CHAPTER 5

RESULTS AND DISCUSSION

5.1. WORKING

The waste is first placed in front of the ultrasonic sensor. The sensor detects the waste and makes the lid of the dustbin to open and the waste is disposed inside the dustbin. This process repeats and goes on like a cycle.

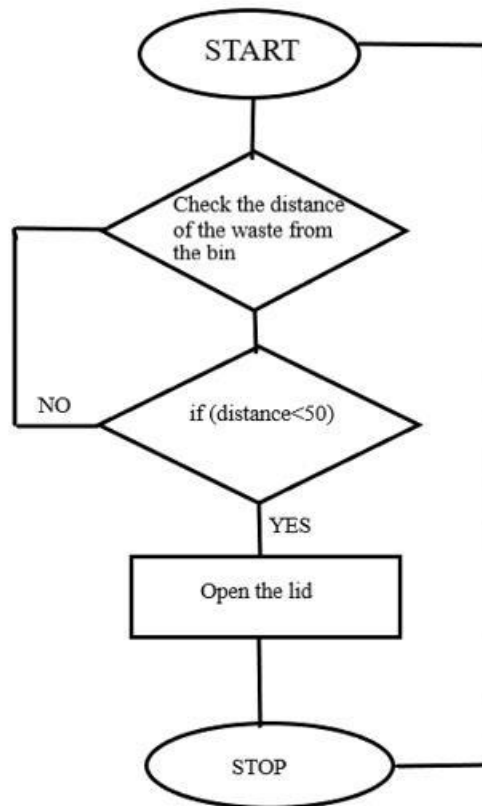


Fig: 5.1: The cycle of the first part of dustbin

Now the waste is collected inside the bin. The NodeMCU is connected to a Wi-Fi hotspot or a connection that is known by giving its SSID and PASSWORD which are

required to connect to a particular network connection. The ultrasonic sensor detects the level of distance of waste inside the bin and is indicated through LED's in the Blynk app. There will be three widgets, each representing a LED. There are three colors: Green LED, This LED indicates that the waste level is very low inside the bin and more waste can be added inside the dustbin. Orange LED, This LED indicates that the waste is half-filled inside the dustbin and more waste can be added into it. Red LED, This LED indicates that the dustbin is full and the waste inside the dustbin need to be emptied. The LED indication happens in real time and also very fast.

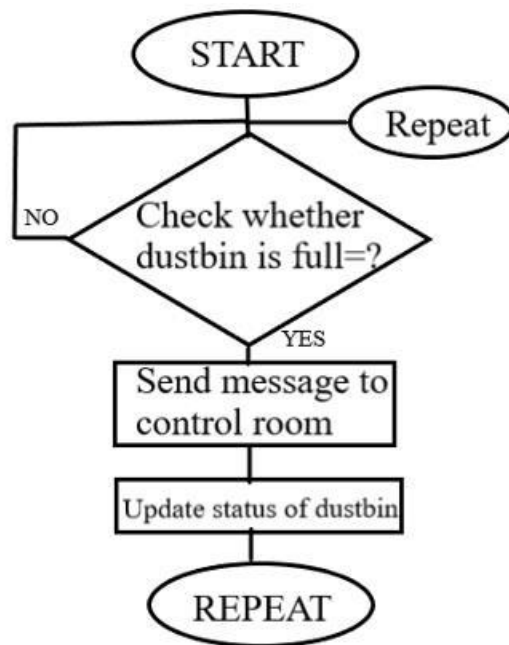


Fig: 5.2: The cycle of second part of the dustbin

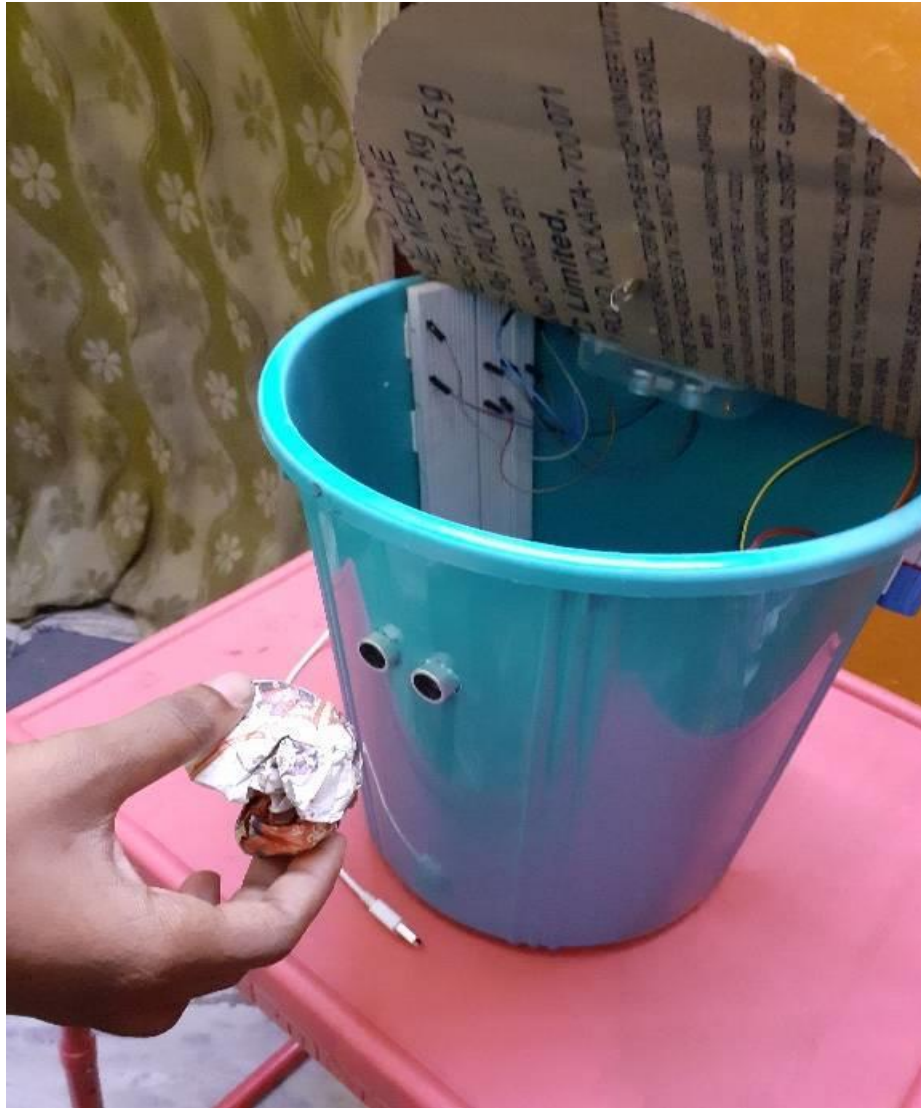


Fig: 5.3: The dustbin's lid is open after the detection of waste

In the fig 5.3, the lid of the dustbin is automatically open when waste is placed on the front part of the dustbin.

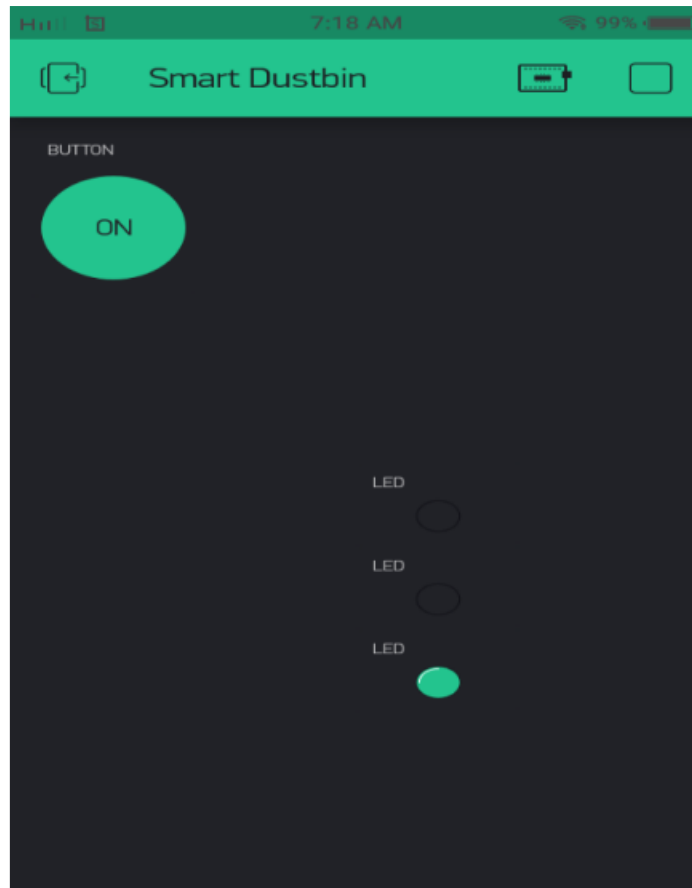


Fig: 5.4: The notification is indicated by Green LED

In the figure 5.4 the notification is shown as Green LED, this indicates the dustbin is empty or contains low level of waste and more waste can be added inside it. This LED will remain as it is when the level of the waste increases.

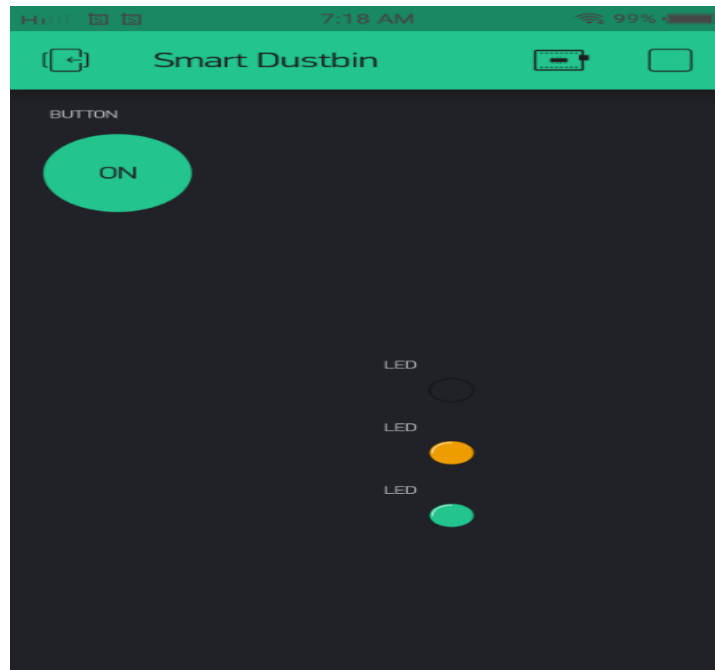


Fig: 5.5: The notification is indicated by Orange LED

In the figure 5.5, the notification is shown as Orange LED and the Green LED because the dustbin is half-filled and some more waste can be added inside it. The green LED will also be glowing because the waste level has risen and the distance between the ultrasonic sensor and waste decreases.

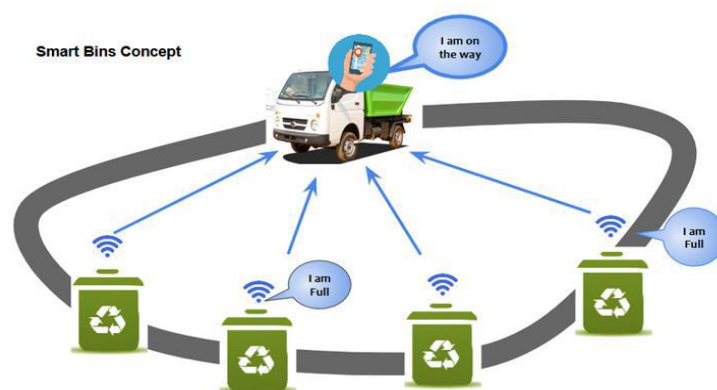


Fig: 5.6: The notification is indicated by all the three LEDs, Red Orange and Green.

In the figure 5.6 the notification is shown as all the three LEDs are glowing where this indicates that the dustbin is full and the waste from the dustbin is needed to be emptied from it and no more waste can be added inside the dustbin. The Orange LED and Green LED will also be glowed because the rise of the waste has increased and the distance is also very less between the ultrasonic sensor and the waste. The main advantage of using this method of implementation is the radiation caused by Wi-Fi is very less and particular carrier signal is not required to get notifications. By maintaining the same SSID and Password of Wi-Fi connection between Mobile and Node MCU board we get the real time notifications.

5.2 PROTOTYPE TESTING

The prototype testing strategy employed was unit testing integration testing and system usability tests. System and Integration testing was conducted by the developer and the target users of the system ensuring the system meets the requirement, performs the tasks as expected and that the solution measures up to the software standards ensuring usability, accuracy, robustness and responsiveness.

This study achieved the test strategies and measured and recorded as per the table 5.1

Test case Name: Integration and System Test				
Test Date:5 th March 2022 Test Description:				
Pre-Conditions:				
Post-Conditions:				
Test teps				
Step	Action	Expected Response	Pass/Fail	Comments
1.	Arduino to Web Service and mobile application Integrations	Fast and reliable push and pull integrations	PASS	Successful
2.	System dashboard, Server side and mobile Application visualizations	Easy to follow dashboards and excellent visualizations	PASS	Successful
3.	Reporting and exporting data in different formatting	Ability to export data from the system	PASS	Successful
4.	System response time and semi-real time reporting	Ability to respond and publish Information fast	PASS	Successful
6.	System configurability	Ability of system to be configured by user according to preferences	PASS	Successful

Table 5.1: Integration and System Tests

5.3 DISCUSSIONS

5.3.1 Introduction

The main findings with regard to the research questions are summarized and general conclusions based on the findings of the studies presented in this thesis are described. Furthermore, the strengths and limitations of this thesis are considered and discussed.

5.3.2 Findings

The findings of the study were obtained from the prototype testing results and the system usability questionnaire administered. Table 5.2 presents some of the results obtained from the system usability survey. The subsections below present a detailed description of the findings.

Table 5.2 System usability survey findings

	No	Yes	Other
<i>The User interface is friendly</i>	9.1%	81.8%	9.1%
<i>I can use the system with Minimum training</i>	18.2%	72.7%	9.1%
<i>I am willing to use this system for monitoring my domestic or Office bin</i>	9.1%	72.7%	18.2%

5.3.2.1 user interface

From the survey, 77.8% of the sample population agreed that the user interface

was very friendly. The other 11% disagreed that it was not friendly, and another 11% responded with other different remarks see figure 5.7

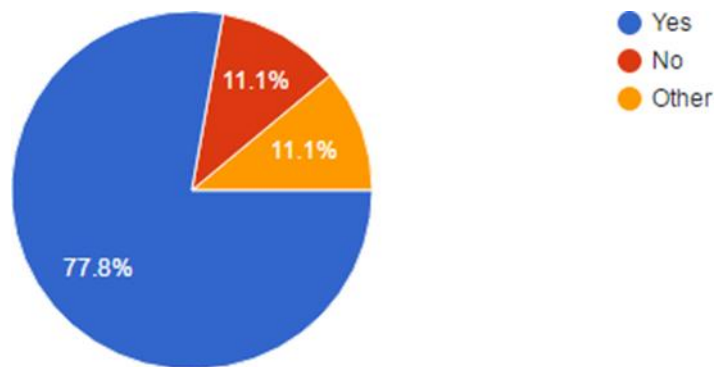


Fig: 5.7: User interface is friendly

In a differently survey questions, 70% respondent that they could use the system with minimum training 20% disagreed with this and another 10% respondent neutrally with different comments. See figure 5.8 below

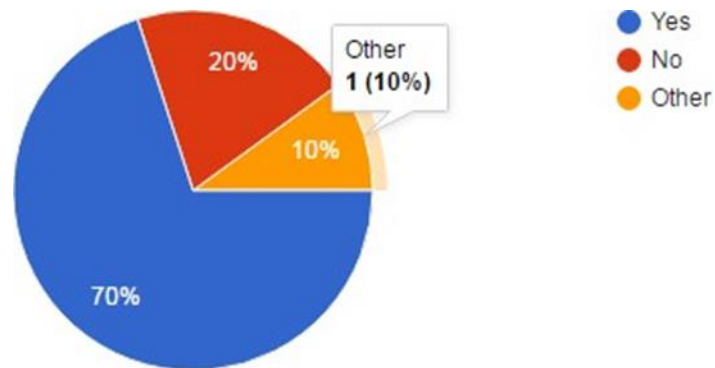


Fig: 5.8: Can use system with minimal training

5.3.2.2 Performance

On performance, we subjected the respondents on the bin monitoring

capabilities of the system. 40% of the respondents agreed that Monitoring bin on pungent smell and fill level is easier and takes shorter duration as compared to the current method. 30% disagreed to this and another 30% respondent neutrally with comments. See figure 5.9 below.

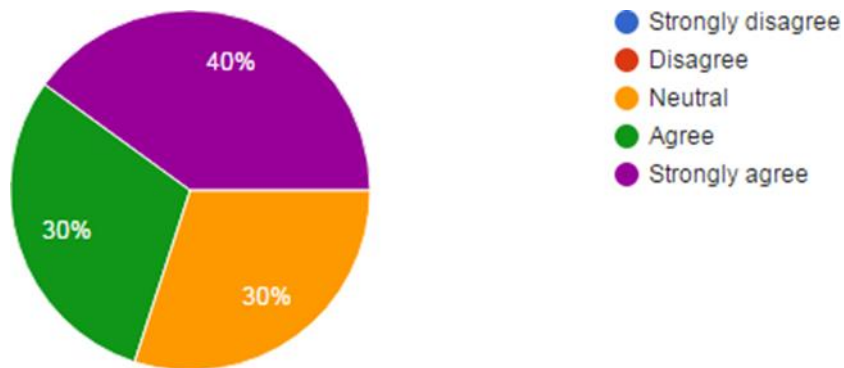


Fig: 5.9: Monitoring is fast and easy

5.3.2.3 Convenience

The convenience was also measured 45.5% strongly agreeing that the system was highly convenient. An additional 36.4% agreeing that the system was convenient. And another 18.2 % were respondent neutrally about this see figure 5.10 below

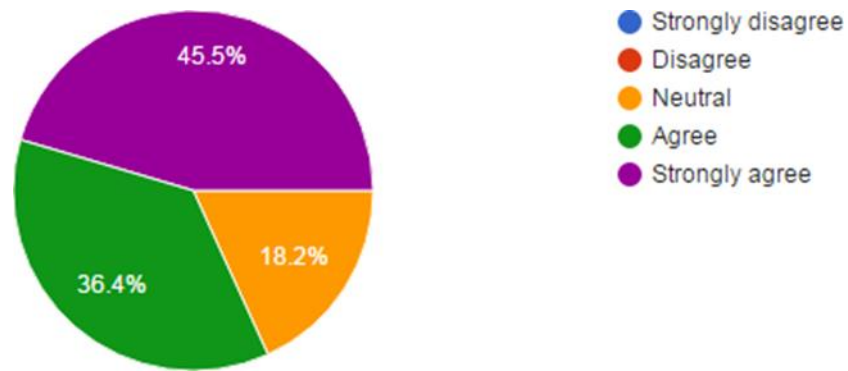


Fig: 5.10: System convenience

5.3.3 LIMITATIONS OF THE PROTOTYPE

Through the study, the researcher noted that the public would want to opt for battery supported smart bins. This research however does not address this issue. Again, a bigger percentage of the population was not completely comfortable with the system requiring Wi-Fi connectivity. The scope of this work though does not cater for this gap.

CHAPTER 6

CONCLUSIONS

6.1 CONCLUSIONS

Managing in – house bins has been an unidentified but highly potential hazard for human habituated areas. The current method of manually peeping through the bins and checking fill – level might lack comprehensiveness as it lacks to measure pungent gaseous content, and would be prone to forgetfulness.

As pinpointed from the research study through the administered questionnaires, most members of the public find it difficult to use the current methods for monitoring bin information over a period of time. The method is dependent on numerous physical checks of the bins. Which makes the method tiresome and non – reliable.

This research therefore takes advantage of the IOT concept and use of algorithms to come up with a sensor based system for detection and monitoring of bin fill level and gas content, and transmit this information to the user via dashboards and reports. The user can also configure notifications and be notified upon certain triggers as bin fill – up

6.2 RECOMMENDATIONS FOR FUTURE WORK

Through this study, the research results identified that the public would want to opt for battery supported smart bins. This research however does not address this issue. I would propose this as a feature for future development. Again, a bigger percentage of the population was not completely comfortable with the system requiring Wi – Fi connectivity. The scope of this work though does not cater for this and would be a keen area of interest for future work.

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