**MACHAKOS UNIVERSITY**

**SCHOOL OF ENGINEERING AND TECHNOLOGY**

**DEPARTMENT OF COMPUTING AND INFORMATION TECHNOLOGY**

**SMART WASTE BIN**

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**THIS PROJECT PROPOSAL IS SUBMITTED IN PARTIAL FULFILLMENT OF REQUIREMENTS FOR THE MACHAKOS UNIVERSITY AWARD OF BACHELOR OF SCIENCE IN COMPUTER SCIENCE.**

**April, 2024**

# **Declaration**

I hereby declare that this project documentation is my original work that represents my ideas and contributions. All the information and concepts presented in this project are accurate to my best of knowledge and its source are reliable and credible references.

Name: ……………………………………………………………………………….

Sign:………………………………………………….

Date: ………………………………….

Supervisor

Name: ………………………………………………………………………………….

Sign: ……………………………………………………

Date: …………………………………….

# **Dedication**

I dedicate this project to my family and friends (Mercymerine Atieno Omondi), whose unwavering support and encouragement have been the driving force behind my academic journey. Your constant motivation and belief in me have been instrumental through my academic journey.

# **Acknowledgment**

I thank God for His unwavering strength, guidance and blessings throughout my academic journey. I am deeply grateful for my family and friends who have supported me immensely and encouraged me throughout my studies.

# **Abstract**

Waste management in rapidly growing cities, is confronted with numerous challenges arising from urbanization population density, inadequate infrastructure, and limited resources. As a result, there has been a significant rise in waste generation and environmental degradation. Although there are established collection points and contracted private companies for waste management, the coverage and frequency of waste collection can be inconsistent, leading to overflowing bins in public areas. Furthermore, inefficient waste collection practices and the lack of real-time monitoring contribute to the unsightly appearance of public spaces and pose health hazards. The accumulation of waste in overflowing bins attracts pests and vermin, creates unpleasant odors, and increases the risk of disease transmission. In addition, the inadequate infrastructure for waste management can lead to improper disposal and environmental pollution, further exacerbating the negative impact on ecosystems and human health.

In response to these challenges, this project proposal presents a Smart Waste bin designed to optimize waste collection operations and promote sustainable waste management practices in rapidly growing cities. The proposed system utilizes smart bin technology equipped with ultrasonic sensors to accurately measure the fill levels in bins. It also encompasses real-time monitoring by the waste management companies addressing the shortcomings of traditional waste management approaches. This facilitates timely waste collection, minimizing overflowing bins and ensuring a cleaner environment. By optimizing resource allocation, reducing unnecessary pickups, and minimizing operational costs, the system aims to enhance overall efficiency in waste collection processes. The proposed Smart Waste Bin offers a solution to improve waste management practices and mitigate environmental impacts in rapidly growing cities.

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# **CHAPTER ONE:**

# **INTRODUCTION**

# **1.1** **Background of Study**

The global economy is currently undergoing a significant transformation driven by globalization and rapid technological progress. This shift is characterized by technology, information, and knowledge emerging as fundamental pillars of this new era (Schwab, 2016). As a result, various aspects of modern life, such as education, professional activities, social interactions, and personal experiences, have been profoundly affected through the widespread adoption of Information and Communication Technology (ICT) (Kaware & Sain, 2015).

Investments in ICT are recognized as a key driver of productivity growth, which lays the foundation for improvements in the standard of living (Aker & Mbiti, 2010). Numerous studies conducted in developed countries at the firm, industry, and country level have shown a positive and economically significant relationship between ICT and productivity (Ardizzi et al., 2013). The productivity effect of ICT has been widely observed, supporting its role in enhancing economic performance.

As globalization and technological change continue to reshape the world, urbanization has become a prominent phenomenon. Urban populations are growing at a faster pace than cities can support, resulting in significant challenges. Cities struggle to provide basic urban services on an unprecedented scale, including housing, electricity, water supply, healthcare, education, and jobs (Harter, n.d.). The rapid growth of city populations has implications for climate change, as urbanization leads to increased consumption levels and the demand for resources, contributing to higher waste volumes (Satterthwaite, 2009).

The consequences of rapid urbanization and population growth present numerous challenges. Strains on infrastructure and resources result in inadequate housing, transportation, and healthcare, while the increased demand for goods and services leads to environmental degradation (Buhaug & Urdal, 2013). This includes elevated pollution levels, greenhouse gas emissions, and deforestation, ultimately impacting the ecosystem and human health. Furthermore, urban areas face significant obstacles in managing solid waste effectively. Improper disposal and management of municipal solid waste (MSW) cause various types of pollution, including air, soil, and water contamination. Inadequate waste management practices can result in health hazards, environmental pollution, and resource depletion (Alam & Ahmade, 2013).

The shift towards a technology-driven global economy has brought about significant changes through the adoption of ICT. ICT investments have been identified as drivers of productivity growth, enhancing economic performance. However, rapid urbanization and population growth pose considerable challenges, including strains on infrastructure, resources, and waste management. These challenges manifest in inadequate housing, transportation, healthcare, and environmental degradation. Effective waste management becomes crucial in mitigating the pollution and health risks associated with urban growth.

**1.2** **Problem Statement**

Waste management companies face significant challenges in optimizing their collection operations. The current approaches often rely on fixed schedules or manual monitoring, resulting in inefficient waste collection and resource misallocation. This leads to unnecessary pickups from bins that are not yet full, contributing to increased costs and environmental impact. Additionally, overflowing bins and inconsistent waste collection schedules affect the aesthetics and cleanliness of public spaces. Hence, an innovative solution is imperative to accurately detect waste levels in bins, promptly monitoring of the bins by waste management companies, and facilitate efficient resource allocation for optimized waste collection.

The proposed solution is an innovative integrated waste bin that combines smart bin technology with real-time monitoring. The smart bins are equipped with ultrasonic sensors, enabling precise measurement of the fill levels in the bins. Once a bin are almost full at a threshold , such as 90% capacity, using real-time monitoring the waste management company know the status of the waste levels in the bin. These real time monitoring can be conveniently used to promptly alert the relevant personnel to schedule timely waste collection. By harnessing the power of this integrated waste bin, waste management companies can effectively optimize resource allocation, minimize unnecessary pickups, reduce operational costs, and achieve enhanced overall efficiency in waste collection processes. Moreover, the solution significantly contributes to environmental sustainability by promoting efficient waste management practices.

**1.3** **Objectives of Study**

**1.3.1 General Objectives**

The main objective is to develop an smart waste bin with sensors to measure waste levels.

### **1.3.2 Specific Objectives**

1. To review and analyze the current waste management systems in place.
2. To design a smart waste bin based on the findings of the review.
3. To develop an smart waste bin for efficient waste collection.
4. To test and validate the new smart waste bin for its performance.

## **1.4 Justification of Study**

The current problem of inefficient waste collection practices, resource misallocation, and compromised aesthetics poses a significant threat to the environment and overall sustainability. The reliance on fixed schedules and manual monitoring leads to overflowing bins, increased costs, and detrimental environmental consequences such as air pollution, soil contamination, and ecosystem degradation. These issues not only affect the immediate surroundings but also contribute to the global challenge of waste management and climate change. By developing an smart waste bin that leverages technology, sensors, and real-time monitoring, the project aims to address these environmental challenges. By optimizing waste collection operations, minimizing unnecessary pickups, and reducing operational costs, the proposed solution seeks to mitigate the negative environmental impact while promoting a cleaner and more sustainable environment. Additionally, the project aligns with Sustainable Development Goal (SDG) number 11: Sustainable Cities and Communities, by striving to create inclusive, safe, resilient, and sustainable cities through advanced waste management practices.

**1.5** **Scope of Study**

This study aims to explore the development and implementation of an smart waste management system with a specific focus on smart bin technology and real-time notifications. It will delve into the design and deployment of smart bins equipped with sensors for accurate waste level measurement. The study will investigate the integration of these smart waste bins into a comprehensive open-source Internet of Things (IoT) platform that includes real-time monitoring so the waste management companies can know when bins reach are almost full. Additionally, the open-source platform will allows the waste collection companies to collect, store, analyze, and visualize data from IoT devices.

## **1.6 Limitations of Study**

1. Connectivity and Network Reliability: Uninterrupted connectivity and reliable network infrastructure are essential for real-time data transmission and notifications, and challenges in this area could affect the system's performance.
2. Power Supply and Energy Efficiency: Ensuring continuous power availability and optimizing energy efficiency for the smart bins and communication devices is important, especially in locations with unreliable power sources.

# **CHAPTER TWO:**

# **LITERATURE REVIEW**

## **2.1 Introduction**

This chapter presents a comprehensive overview of the existing literature on Waste Collecting Management System principles, theories, and their operational mechanisms in achieving their intended goals. The focus of this literature review is centered on the management of waste collection using the Waste Collecting Management System, aiming to establish a solid theoretical foundation for the development of waste collection systems in the specific region. By drawing insights from previous studies, this chapter seeks to identify key considerations and best practices for the design and implementation of efficient waste collecting systems, ultimately informing the construction of an effective and sustainable waste management infrastructure.

## **2.2 Existing Systems**

### **2.2.1 TakaTaka Solutions**

TakaTaka solutions is a waste management company in Kenya that has implemented a comprehensive and integrated waste management system which includes waste collection, sorting, recycling and composting. They offer waste management services to all types of waste producers residential houses and apartments, office building, restaurants, schools, shopping malls, factories and hospitals. They provide their customers bins and bin liners in different colors to make it easier to source separate the waste. They then schedule waste collection methods such as door-to-door collection and collection points, they ensure the proper segregation and handling of different waste streams.

### **2.2.2 Bins Group**

Bins (Nairobi) Services Limited, incorporated in 1986, is a leading garbage collection, disposal, and recycling company in Nairobi. With over three decades of experience, the company has established itself as a reliable and reputable service provider in the industry. Their services include collection of household garbage, green Waste and bulky Items, collection, disposal and recycling of commercial, industrial and construction waste. Known for their reliability, the company ensures scheduled pickups and prompt responses to customer requests, offering high-quality and professional garbage collection services.

### **2.2.3 Colnet Limited Kenya**

Colnet Limited offers a comprehensive range of waste management services, ensuring that their clients have access to suitable containers that match their waste production requirements. Their commitment to prompt collection services ensures that waste is efficiently removed from the client's premises. A key focus of the company is to handle waste legally, environmentally, and with minimal disruption to their clients' businesses. By utilizing the latest disposal technologies, Colnet Limited ensures that their services are efficient and responsible. They provide customized waste pickup programs for various needs, including curbside pickup for residential areas, commercial and industrial collections, yard waste pickup, bulk waste pickup, food and organic waste pickup, and scheduled waste pickup. The availability of dumpsters further enhances their waste disposal capabilities.

### **2.2.4 Waste Afrika Kenya**

Waste Afrika Kenya Solid Waste Advisory Services is a specialized company in Kenya that offers a range of solid waste management services and consultancy. Their expertise lies in the safe removal and disposal of asbestos-containing materials, demonstrating a strong commitment to handling hazardous waste responsibly and ensuring environmental and human safety. In addition, the company provides integrated solid waste management services and consultancy, encompassing source reduction, source separation, recycling, and materials recovery. By promoting sustainable practices, Waste Afrika Kenya contributes to the efficient use of resources and minimizes waste generation. Their emphasis on safe storage and handling of hazardous materials reflects their dedication to preventing environmental pollution and protecting public health. Overall, Waste Afrika Kenya Solid Waste Advisory Services appears to be a reliable and environmentally conscious company, providing comprehensive solutions for solid waste management in Kenya.

### **2.2.5 Kamongo Waste Paper Kenya**

Kamongo Waste Paper Kenya is a reliable and customer-oriented company that specializes in waste paper collection and recycling services in Kenya. They have a proven track record of collecting large quantities of waste paper on a daily basis throughout the country. Their waste paper collection services provide a convenient and responsible solution for businesses and individuals seeking proper disposal options. Additionally, Kamongo Waste Paper Kenya offers goods and parcels transportation services, ensuring reliable and guaranteed delivery of goods across Kenya. Their emphasis on recycling, particularly focusing on old newspapers, demonstrates their commitment to promoting sustainable practices and contributing to the circular economy. Moreover, their paper shredding service enables businesses to securely dispose of sensitive documents while maintaining confidentiality. Kamongo Waste Paper Kenya is a reputable company that provides comprehensive waste management solutions, promoting environmental conservation and resource optimization.

## **2.3 Research Gaps**

The existing waste management systems reviewed, including TakaTaka Solutions, Bins Group, Colnet Limited Kenya, Waste Afrika Kenya, and Kamongo Waste Paper Kenya, demonstrate certain gaps that can be addressed by a smart bin project. These gaps include the lack of integration of smart technology in waste management operations, limited waste segregation options, inadequate tracking and monitoring capabilities, insufficient focus on recycling and the circular economy, limited hazardous waste management measures, and the absence of integration with transportation services. By incorporating smart bins with advanced features, such as real-time monitoring, and data analytics, a smart bin project could provide a comprehensive waste management solution that optimizes waste segregation, enhances recycling efforts, improves operational efficiency, and delivers personalized services to customers while integrating with transportation services for more efficient waste transportation. **From a financial standpoint, a smart bin project represents a sound investment with the potential for significant returns.** The cost savings achieved through improved operational efficiency and reduced waste disposal expenses can quickly offset the initial investment in smart bin technology.

# **CHAPTER THREE:**

# **RESEARCH METHODOLOGY**

## **3.1 Introduction**

The aim of this chapter is to introduce the research methodology that will be utilized in the development of the Smart Waste Management System. Research methodology encompasses the systematic approaches and techniques employed to gather, select, process, and analyze relevant information in a research project. In this chapter, an overview of the research methods to be employed will be provided, outlining the steps to be taken in gathering and analyzing data for the implementation of the Smart Waste Management System.

### **3.2 Research Design**

The research design involves a mixed-methods approach that combines quantitative and qualitative methods. Surveys will be utilized to gather quantitative data on waste management practices and perceptions, while in-depth interviews will provide qualitative insights into system requirements and expectations. Direct observations at waste collection points and sensor data collection will provide real-time data on bin usage and performance. User feedback and field testing will contribute to assessing usability and effectiveness. Through an iterative process aligned with Agile principles, the research design allows for continuous improvement based on data analysis, user input, and field testing, ensuring the integrated waste management system meets stakeholder needs and enhances waste collection efficiency and sustainability.

## **3.3 Population and Sampling Method**

### **3.3.1 Population**

The target population consists of waste collection companies and waste collection points. Waste collection companies are key stakeholders responsible for waste management operations, providing insights into current practices and requirements. Waste collection points represent various locations where smart bins will be implemented, allowing for data collection on bin usage patterns and collection efficiency. Engaging with them enables a comprehensive understanding of waste management practices and facilitates the development of an optimized smart bin system.

### **3.3.2 Sampling Method**

For this smart bin project, I will employ purposive sampling as the sampling method. Purposive sampling involves purposefully selecting waste collection companies and specific waste collection points that are representative of different locations, waste volumes, and waste management practices. This method will enable the research team to gather targeted and in-depth information from key stakeholders directly involved in waste management operations. By purposefully selecting participants with expertise and firsthand knowledge in waste collection, the research project can gain valuable insights into the current practices, challenges, and expectations related to the integrated waste management system. The purposive sampling approach ensures that participants have relevant expertise and insights specific to the smart bin project, allowing for a focused exploration of their perspectives. This method will facilitate a deeper understanding of the specific waste management context and provide valuable information to inform the development and optimization of the smart bin system for improved waste collection practices.

**3.4 Methods of Data Collection**

Data collection for the smart bin project will involve surveys, interviews, and observations. These methods enable a comprehensive understanding of waste management practices and the effectiveness of the smart bin system.

### **3.4.1 Surveys**

Surveys will be designed and distributed in electronic or in print form to waste management companies, municipal authorities, residents, or other relevant stakeholders. The respondents will be given a designated time-frame to complete the surveys, and the collected data will be compiled for analysis. Surveys will gather quantitative data on waste management practices, perceptions, and feedback.

### **3.4.2 Interviews**

It entails conducting in-depth interviews with key stakeholders, such as waste management company representatives, municipal officials, or residents. These interviews will be conducted face to-face or over the phone depending on the availability and preferences of the participants. The interviews will follow a structured or format to ensure consistency in data collection, and they will be documented through notes for later analysis. Interviews will allow for gathering qualitative data and obtaining detailed insights into their experiences, opinions, and suggestions.

### **3.4.3 Observations**

This is about making direct observations at waste collection points or designated areas to collect observational data on bin usage patterns, waste generation rates, or collection efficiency. It will involve physically visiting waste collection points or designated areas to directly observe and record information on bin usage patterns, waste generation rates, and collection efficiency. Then document the observations, including timestamps, descriptions, and any relevant details, to capture the real time practices and behaviors accurately.

## **3.5 Data Analysis**

The collected data from surveys, interviews, and observations will be analyzed using both qualitative and quantitative analysis methods to derive meaningful insights and address the research objectives of the smart bin project.

### **3.5.1 Quantitative Analysis**

Quantitative data obtained from surveys will be analyzed using statistical techniques. This analysis will involve calculating descriptive statistics, such as frequencies, percentages, and measures of central tendency, to summarize and describe the survey responses. Inferential statistics may also be applied to examine relationships between variables or test hypotheses, allowing for deeper insights into waste management practices and perceptions.

### **3.5.2 Qualitative Analysis**

Qualitative data obtained from interviews and observations will be analyzed using thematic analysis. This analysis approach involves identifying recurring themes, patterns, and concepts within the interview transcripts and observational notes. The data will be carefully reviewed, coded, and organized into meaningful themes and sub-themes, allowing for a rich understanding of stakeholders' experiences, opinions, and suggestions related to the smart bin project.

### **3.5.3 Integration and Interpretation of Findings**

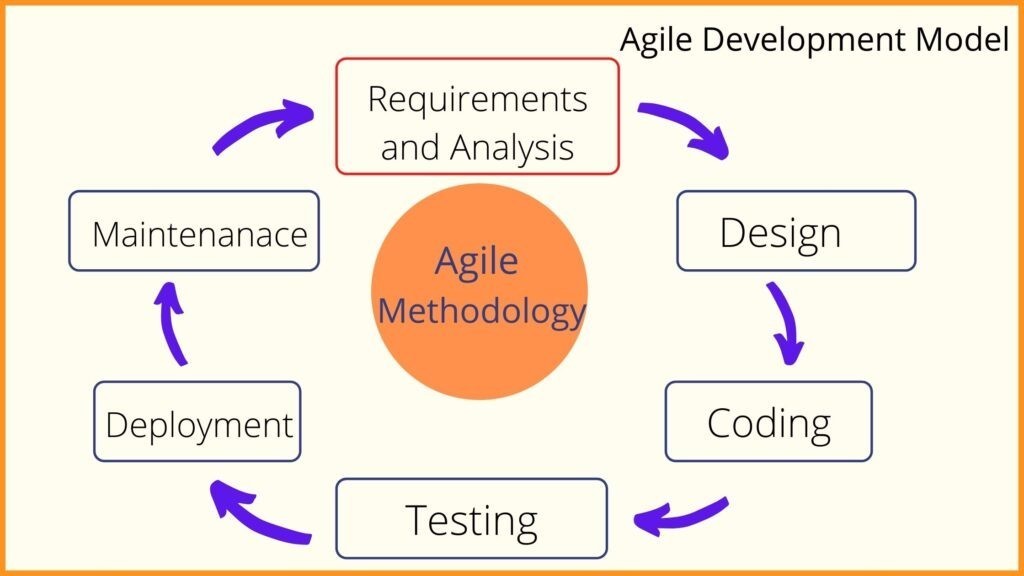
The findings from the quantitative and qualitative analyses will be integrated and interpreted to provide a comprehensive understanding of the smart bin project. The results will be synthesized, allowing for the identification of key themes, trends, and insights across the data sources. The integrated findings will be discussed in the context of the research objectives and the practical implications for optimizing waste management process Integration and enhancing the effectiveness of the smart bin system.

## **3.6 Process Model**

The process model for this Project outlines a structured framework that guides the development and implementation of the smart waste management system. It ensures an organized and efficient approach, enabling effective resource management and progress tracking throughout the project life cycle. Agile will be the process model for the project.

### **3.6.1 Agile Model**

The Agile model has been chosen for the smart bin project due to its adaptability in a rapidly evolving technological landscape. This methodology allows for quick responses to changes, incorporation of feedback from stakeholders and end-users, and incremental improvements throughout the development process. By breaking the project into shorter iterations called sprints, functional increments of the smart bin system can be delivered, user feedback can be gathered, and risks can be effectively mitigated.

Figure 3.1: Process Model

#### **3.6.1.1 Requirement Analysis**

It involves identifying and understanding the specific needs and expectations. It includes conducting thorough research on waste management practices, conducting surveys and interviews to gather user requirements, and analyzing existing systems and technologies. The gathered information will be used to define the functional and non-functional requirements of the smart bin system, ensuring it addresses the key challenges and provides the desired features and functionalities.

#### **3.6.1.2 System Design**

This involves designing the overall structure of the smart bin system, including the hardware components, software modules, and data management mechanisms. This phase also involves defining the user interface, communication protocols, and data flow between the smart bins and the central management system. The design will be based on the identified requirements and will aim to optimize waste collection, monitoring, and management processes.

#### **3.6.1.3 Development and implementation**

The development and implementation phase involves translating the system design into a functional smart bin system. This includes coding and programming the software, integrating hardware components such as sensors and configuring the necessary infrastructure. The implementation process will also include testing to ensure the system functions correctly and meets the defined requirements.

#### **3.6.1.4 Quality assurance**

Quality assurance ensures that the system meets the desired quality standards. This involves conducting comprehensive testing, including functional testing and performance testing to validate the system's performance and reliability. Any identified issues or bugs will be addressed and resolved to ensure the system operates smoothly and provides accurate waste management outcomes.

#### **3.6.1.5 Deployment and Maintenance**

This involves installing the smart bins, configuring the communication infrastructure, and connecting them to the central management system. Once the system is set up, I will perform testing and evaluation to assess its functionality, performance, and effectiveness. This will involve simulating waste generation, monitoring the fill levels, and analyzing the data collected. There will also be maintenance procedures that will be established for regular monitoring and maintenance activities to ensure the system operates efficiently, any issues are addressed promptly, and necessary updates or enhancements are implemented to improve system performance and functionality.

# **CHAPTER FOUR:**

# **SYSTEM DESIGN AND ANALYSIS**

## **4.0 Introduction**

This chapter delves into the Smart Waste Bin’s analysis and design. It dissects current waste bins, pinpoints challenges, and unveils improvement prospects. Navigating through system design, it emphasizes architectural decisions, data flow, and component interactions. The synergy between analysis and design is highlighted, revealing the systematic approach employed to craft an innovative waste management solution.

## **4.1 Data Analysis Results**

During the data analysis phase for the Smart Waste Management System project all of the data collected via surveys, interviews, and direct observations was carefully examined. The surveys yielded quantifiable data that offered insightful information about stakeholder opinions and the state of waste management techniques today. Statistical methods such as percentages and frequency distributions were used to analyze the replies. One noteworthy conclusion is that respondents generally agreed about the difficulties encountered in garbage collection; a sizable portion of them brought up problems with ineffective pickup schedules and overflowing bins in public spaces

### **4.1.1 Surveys**

The results of the survey during the data analysis is the quantitative insight into the existing waste management practices and the perception of the stakeholders. The population sample included waste management professionals, municipal authorities and residents, who provided the understanding on the prevailing challenges within the waste collection system. Most of the issues that were identified include inefficient pickup schedules and overflowing bins in public spaces. This resulted to the need of a more dynamic and responsive approach in waste management.

### **4.1.2 Interviews**

Through interviews with key stakeholders, led to qualitative aspect to the data analysis. A usual idea that came up from the interviews recommended a collective interest in the integration of real-time monitoring systems. The stakeholders expressed the necessity for technology driven solutions to address challenges promptly. The interviews provided a detailed and insightful look at the challenges in waste management and also the views of the people in the field.

### **4.1.3 Observations**

This involved direct observation at waste collection points which offered real-time information about how they are filled, how they are emptied and where there are challenges in operations of the current waste management system. The information from the observation showed that there is a need for a new waste management system that is capable of adjusting to needs of people who produce waste and optimize resource allocation based on real time demand.

## **4.2 Requirement Analysis**

The requirement analysis phase is important as it helps to establish the functionalities of the smart waste bin and also define its characteristics. It outlines the key aspects of the project’s functional and non-functional requirements, which are derived from the analysis of data, surveys, interviews and observations. It serves as a basic document with the goal of establishing agreement among it users and the developers and an all inclusive guide for the design and development of the project in order to meet its intended objectives.

### **4.2.1 The Functional Requirements**

The functional requirements outline the specific actions and capabilities that the smart waste bin must deliver. It ensures the bin’s ability to effectively manage waste by including tasks such as waste collection and resource allocation. The data gathered from the data analysis result provided an understanding into the waste generation patterns, collection schedules and the needs of the users. The following are the system's requirement for the project:

1. Real time waste level Monitoring

There will be continuous monitoring and providing real-time updates on waste levels in waste bins.

1. Data Publishing to Adafruit IO.

For the remote access and analysis, waste level data will be published to the Adafruit IO

1. Alert Mechanism when waste levels reach critical thresholds, there will be trigger alerts.

### **4.2.2 The Non Functional Requirements**

The non-functional requirements focus on the performance characteristics of the bin by ensuring its reliability, scalability and maintainability. Observations and analysis of data helped in assessing the bin’s ability to handle varying waste volumes and adapt to advancement in technology. The following are the non-functional requirements for the project:

1. Performance

Minimal latency in waste level updates should be assured.

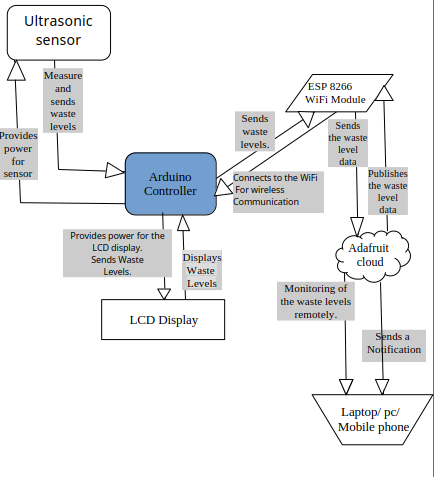
1. Maintenance and usability

It should be easy to maintain and navigate through its functionality.

1. Availability

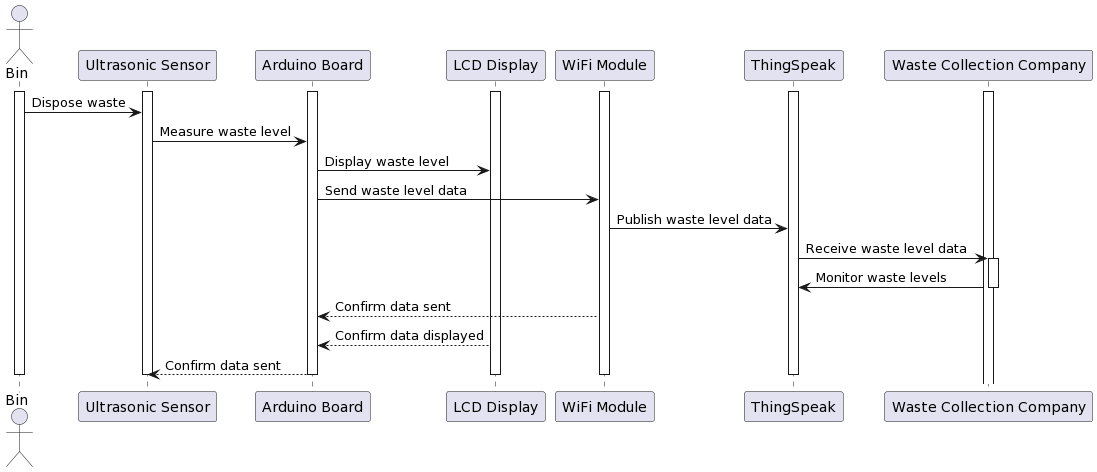
It should always be available, with minimum downtime for maintenance and upgrades.

## **4.3 Propose Bin Architecture**



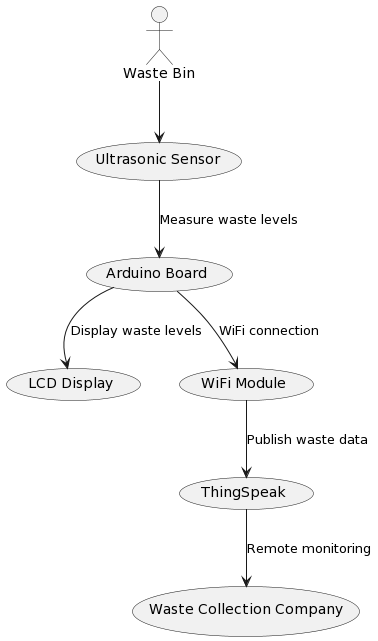
*Figure 4.1 Proposed Bin Architecture*

## **4.4 Bin Sequence Diagram**

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*Figure 4.2 Bin Sequence Diagram*

## **4.5 Data flow Diagram**

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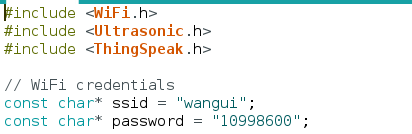
*Figure 4.3: Bin data-flow diagram*

## **4.6 Code Implementation**

This section discusses the key aspects of the code implementation for the smart waste bin.

### **4.6.1 WiFi Configuration**

Configure WiFi credentials for connecting the ESP32 to the local network.

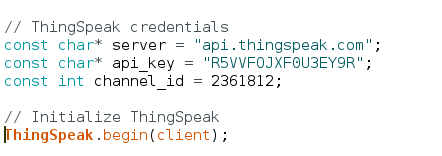


*Figure 4.4: WiFi configuration*

The ssid and password variables store the credentials required to connect the ESP32 to the local WiFi network. These are essential for enabling communication between the device and the ThingSpeak server.

### **4.6.2 ThingSpeak Integration**

Establish a connection to the ThingSpeak API and update waste level data.

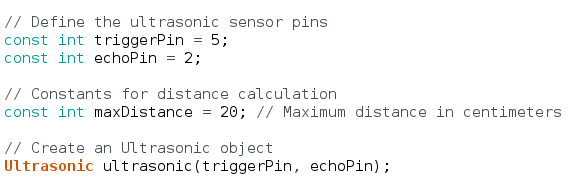


*Figure 4.5: ThingSpeak Integration*

The server, API key and channel id variables store the ThingSpeak server details and channel information. The ThingSpeak.begin(client) initializes the ThingSpeak library, allowing the ESP32 to send data to the specified ThingSpeak channel.

### **4.6.3 Ultrasonic Sensor Configuration**

Define the pins for the ultrasonic sensor and set constants for distance calculation.

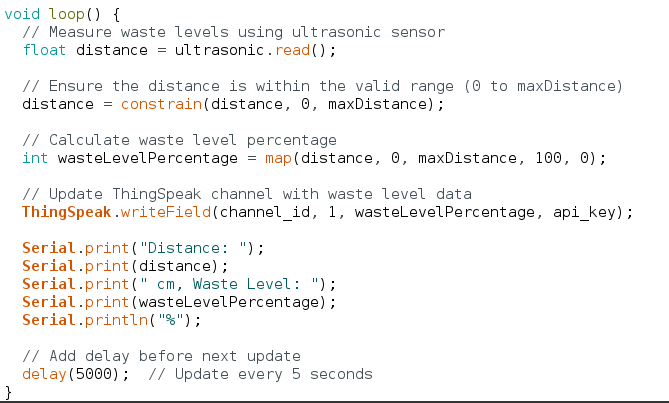
****

*Figure 4.6: Ultrasonic Configuration*

The trigger pin and echo pin variables define the GPIO pins connected to the trigger and echo pins of the ultrasonic sensor. The maxDistance constant sets the maximum valid distance for waste level measurement. An Ultrasonic object is created to interface with the sensor using these pins.

### **4.6.4 Waste level Measurement and update**

Read data from the ultrasonic sensor, calculate waste level percentage, and update ThingSpeak.



*Figure 4.7: Waste level measurement*

The loop() function continuously measures waste levels using the ultrasonic sensor, ensuring the distance is within the valid range. It then calculates the waste level percentage and updates the ThingSpeak channel with the data. Serial prints provide real-time feedback, and a delay is added to control the update frequency.

## **4.7 Compilation and Upload Process**

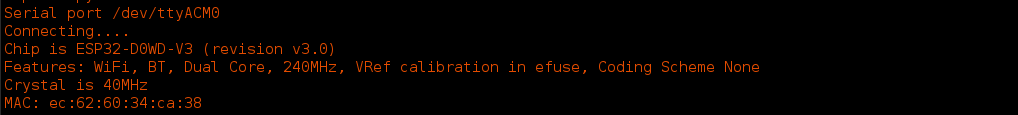
This section shows the process of compiling and uploading the Arduino sketch to the ESP32 microcontroller. This section provides insights into the build options, memory usage, and firmware writing process.

### **4.7.1 Build Options and Memory Usage**

*Figure 4.8: Building options*

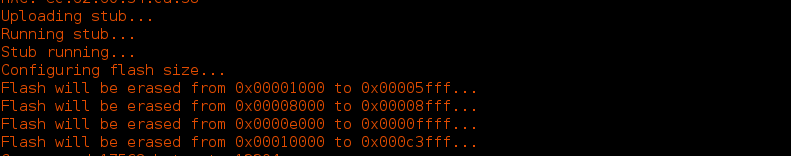
This output reflects changes in build options, the archiving of the core, and details about the program and dynamic memory usage. The sketch uses 726,941 bytes (55%) of the program storage space and 44,172 bytes (13%) of dynamic memory.

### **4.7.2 ESP32 Chip Information**

*Figure 4.9: ESP32 chip Information*

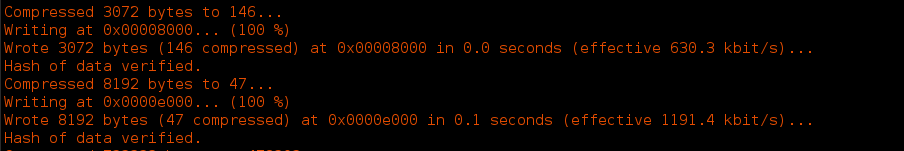
This section provides information about the esptool.py version, serial port connection, and details about the ESP32 chip, including its type (ESP32-D0WD-V3), features (WiFi, Bluetooth, dual-core, etc.), crystal frequency (40MHz), and MAC address.

### **4.7.3 Flash Memory Configuration and Erasing**

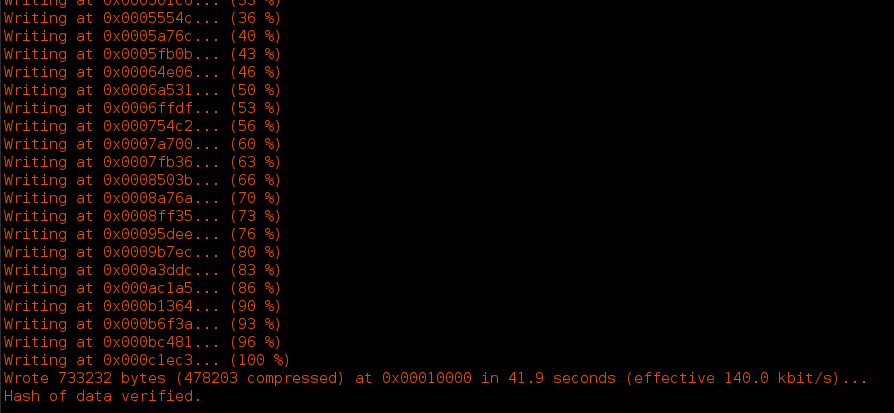
*Figure 4.10: Configuration of the flash memory*

This section involves the upload of a stub, configuration of the flash size, and erasing specific regions of flash memory in preparation for writing new firmware.

### **4.7.4 Writing Firmware to Flash Memory**

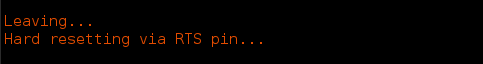
*Figure 4.11: writing firmware*

This part describes the compression of data, writing of compressed bytes to flash memory, and verification of data integrity using hash verification.

*Figure 4.12: Writing of flash memory*

This part provides details about the progressive writing of compressed bytes to different addresses in flash memory and the verification of the hash of the written data.

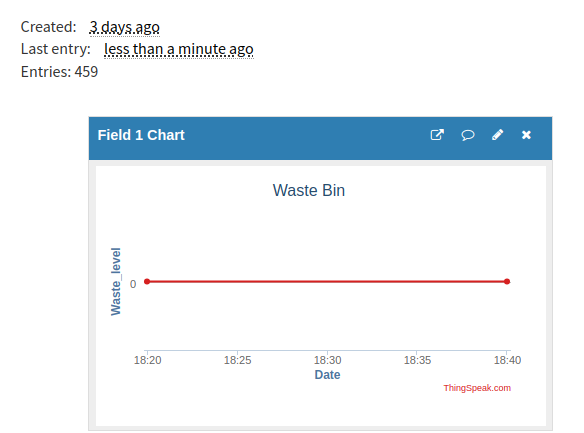
### **4.7.5 Completion and Reset**

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*Figure 4.13: Resting and completing*

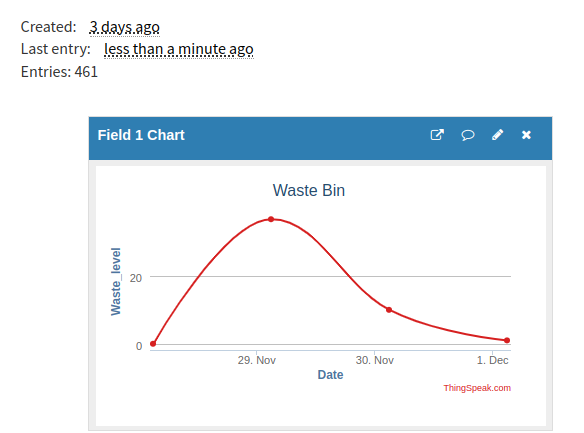
This Indicates the completion of the upload process and initiates a hard reset of the ESP32 using the RTS (Request to Send) pin.

**4.8 ThingSpeak Chart: Waste Level Monitoring**

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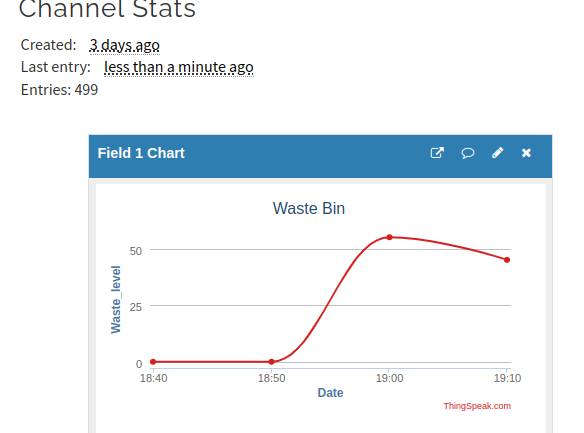
*Figure 4.14: ThingSpeak chart 1*

In this chart the waste levels are at 0% thus showing that the bin is empty.

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*Figure 4.14: ThingSpeak chart 2*

While in this chart it shows the an increase in percentage through the day thus it showing how the bin’s waste levels increase.



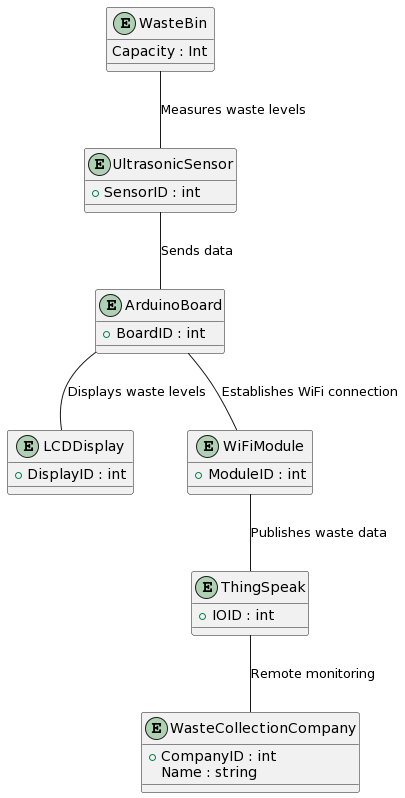
*Figure 4.14: ThingSpeak chart 3*

This chart also shows the percentage level increase thus showing waste levels in the bin also increasing.

**4.9 System Behavior**

The ESP32 continuously measures waste levels using the ultrasonic sensor, calculates the waste level percentage, and updates the ThingSpeak channel. This real-time data allows for remote monitoring of waste levels through the ThingSpeak platform and so the waste collection company can schedule for waste collection.

**4.10 Entity Relationship Diagram**

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*Figure 4.15: Entity Relationship Diagram*

# **CHAPTER 5:**

# **IMPLEMENTATION AND TESTING**

## **5.0 Introduction**

This section provides an overview of the tools used in the development of the Smart Waste Bin, it outlines the comprehensive testing procedures employed, and discusses the proposed system changeover.

## **5.1 Development tools**

The Smart Waste Bin system incorporates a diverse set of technologies for both the front and back end, ensuring robust waste level measurement and monitoring.

1. Arduino Micro Controller

The Arduino micro controller acts as the brain of the Smart Waste Bin, facilitating communication between components and executing the logic for waste level measurement.

1. Ultrasonic Sensor

The Ultrasonic sensor is a crucial component responsible for accurate waste level measurement. It utilizes ultrasonic waves to determine the fill level of the waste bin.

1. LCD display

The LCD display provides a clear and visible interface for presenting waste level information. It enhances user interaction and provides real-time updates on the bin's status.

1. WiFi Module (ESP32)

The ESP32 WiFi module plays a pivotal role in establishing connectivity, enabling seamless communication between the Arduino board and ThingSpeak. It ensures efficient data transmission for waste level monitoring.

1. ThingSpeak

ThingSpeak serves as the cloud platform, replacing Adafruit IO. It facilitates the publication and remote monitoring of waste level data. This platform ensures efficient data management and accessibility for waste collection authorities.

1. Programming language

The logic of the Smart Waste Bin system is implemented using the Arduino programming language, providing a flexible and efficient platform for micro controller programming.

1. Arduino IDE

Arduino IDE is the integrated development environment used for coding and uploading sketches to the Arduino micro controller. It provides essential features such as code editing, compilation, and uploading to the Arduino board.

## **5.2 Testing**

The testing procedures for the Smart Waste Bin are comprehensive, covering unit testing, integration testing, and performance testing to ensure the bin's reliability and efficiency.

### **5.2.1 Unit Testing**

Unit testing strategy entails each component undergoing rigorous unit testing, including the Ultrasonic sensor, Arduino micro controller, WiFi module, and ThingSpeak integration. This ensures the individual functionality and reliability of each component.

### **5.2.2 Integration Testing**

Integration testing is conducted to verify the seamless interaction between bin components. Special emphasis is placed on validating the data flow from the Ultrasonic sensor to ThingSpeak, ensuring accurate and timely waste level updates.

### **5.2.3 Performance Testing**

Performance testing evaluates the bin’s responsiveness and stability under varying waste level scenarios. This ensures that the Smart Waste Bin system operates reliably in real-world conditions, meeting the demands of waste monitoring.

### **5.2.4 Arduino Sketch Testing**

The Arduino sketches are thoroughly tested within the Arduino IDE to identify and rectify any code-related issues. This includes checking the accuracy of data transmission, synchronization with ThingSpeak, and proper functioning of the LCD display.

### **5.2.5 User Acceptance Testing**

User acceptance testing involves end-users validating the system's functionality. This phase ensures that the Smart Waste Bin system meets user expectations and requirements, providing valuable insights for further improvements.

### **5.4 Proposed System Changeover**

The Smart Waste Bin's transition plan meticulously outlines key steps for deployment, user training, and ongoing support. Following a systematic approach guarantees a seamless changeover and maximizes the system's effectiveness in waste management. Users are guided through the process, ensuring a smooth transition and optimal utilization of the smart waste bin.

### 

# **CHAPTER SIX:**

# **DISCUSSION, RECOMMENDATION AND CONCLUSION**

## **6.1 Introduction**

This chapter offers a comprehensive assessment of the implementation of the Smart Waste Bin project, drawing conclusions and proposing future enhancements based on the results. The challenges addressed in the development process and the potential for further advancements are explored. The project aimed to achieve specific objectives:

The project aimed to achieve specific objectives:

1. Integrate Arduino, Ultrasonic Sensor, and LCD Display for waste level measurement.
2. Incorporate the ESP32 WiFi Module for data transmission to ThingSpeak.
3. Develop a system for remote waste level monitoring using ThingSpeak.
4. Evaluate the system's performance in waste management.

## **6.2 Discussion**

The Smart Waste Bin project's conceptual framework drew inspiration from extensive literature and models within the field of waste management. The project successfully achieved its primary objective of implementing an automated waste monitoring system. The significance of the Smart Waste Bin system for both waste collection companies and the local populace cannot be overstated. For waste collection companies, the system streamlined order management, user administration, and service offerings, replacing the cumbersome manual processes involving phone calls. The introduction of real-time monitoring and data reporting contributed to enhanced operational efficiency, marking a pivotal shift towards modern and effective waste management practices.

## **6.3 Implementation Assessment**

The implementation successfully integrated the Arduino board, Ultrasonic sensor, and LCD display for accurate waste level measurements. The ESP32 WiFi module facilitated seamless data transmission to ThingSpeak, enabling remote waste level monitoring. The coding logic ensured reliable and real-time data communication between system components.

## **6.4 Testing and Validation**

Various testing procedures were employed to validate the Smart Waste Bin system:

1. Unit Testing - Each component, including the Ultrasonic sensor, Arduino board, WiFi module, and ThingSpeak integration, underwent rigorous unit testing to ensure individual functionality.
2. Integration Testing - Verified the seamless interaction between system components, validating data flow from the Ultrasonic sensor to ThingSpeak.
3. Performance Testing - Evaluated the system's responsiveness and stability under different waste level scenarios, ensuring reliable operation.

## **6.5 Future Enhancements**

To further enhance the Smart Waste Bin system, potential future enhancements include:

1. Enhanced User Interface: Implement a user-friendly interface for waste collection companies to efficiently manage and schedule collections.
2. Machine Learning Integration - Explore the integration of machine learning algorithms for predictive waste level analysis and optimization of collection schedules.

## **6.6 Conclusion**

The Smart Waste Bin system successfully addressed the challenges of efficient waste management. The integration of hardware components and the establishment of remote monitoring through ThingSpeak showcased the system's viability. Testing procedures confirmed the reliability and stability of the system. Future enhancements, such as a notification system and machine learning integration, present opportunities for further optimization and innovation in waste management practices. Overall, the Smart Waste Bin project marks a significant step towards intelligent and sustainable waste collection solutions.

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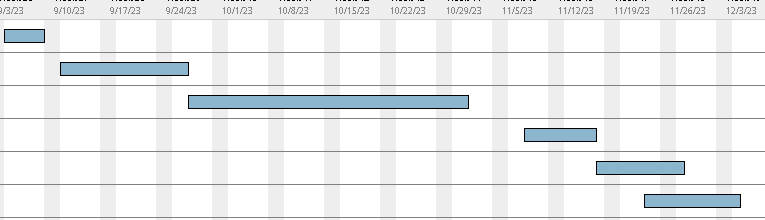
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# **7.0 Appendices**

## **Project Schedule**

*Table 3.1 project schedule*

| Project Activity | Duration in weeks |
| --- | --- |
| Requirement Analysis | 1 |
| System Design | 2 |
| Development | 6 |
| Testing | 1 |
| Deployment | 1 |
| Maintenance | 1 |
| Total | 12 Weeks |

*Figure 7.1 Gantt chart*

## **Budget**

*Table 3.2 Budget*

|  |  |
| --- | --- |
| **Items** | **Price** |
| 1. Bin | Ksh 350 |
| 1. Ultrasonic Sensors | Ksh 500 |
| 1. Arduino micro controller | Ksh1000 |
| 1. Cables and connectors | Ksh 700 |
| 1. Battery | Ksh 1000 |
| 1. Survey | Ksh 1000 |
| Total | Ksh 4550 |