

Application of Smart Waste Management System: Case Study for Queen II Hospital, Maseru Lesotho

By

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Declaration

I declare that this is an individual work done myself to the best of my knowledge. For extra help and learning purposes, the dissertation makes references to and contains quoted materials from previous related researches where needs be, otherwise I believe that the dissertation contains no material written by another person or else submitted to any university.

I, Makamohelo Valentine Mathe

_____ Signature

_____/_____/_____ Date

Dedication

I would like to dedicate this research to my wonderful family. Extend my appreciation to my husband Mr. Mohlanka Mathe and my lovely children Refiloe, Bohlale and Bohlokoa Mathe.

Acknowledgements

I would like to give thanks to Almighty God for his mercy and love and providing me with utmost strength that carried me through ought this research. Secondly I would like to pass my sincere gratitude to my supervisor Dr. Srinath Doss for his continued guidance and corporation.

I convey my deep appreciation for my husband in believing in me, a big thanks to all who contributed in various ways from the start to the end of this dissertation.

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Abstract

Many countries desire to have a clean and healthy environment hence the need for effective and efficient Management of trash Bins. But for many years, the traditional way of collection and removal of trash has not proved to be effective. There are number of problems encountered with the usage of the traditional way of collecting trash in hospital and Healthcare Centers. These problems include among others: trash overflow, land and air pollution and unclean and unhealthy environment.

The main objective of these paper is to overcome all these unfavorable conditions above by mitigate the waste that is always found scattered all over the place. The system uses Arduino to excel communication. Smart Trash Bin (STB) is a Trash bin are interfaced with an ultrasonic sensor which is meant to measure the distance of trash in the bin to the required level. Arduino microcontrollers connected to ultrasonic sensor send data directly in to excel using “PLX-DAQ, a Parallax microcontroller data acquisition add-on tool for Microsoft Excel” (Parallax Inc , 2019).

The status of the bins is monitored through Arduino to excel communication, and provides real-time automated information to the control Center of the trash collection company. In addition to this Arduino to excel communication, graphs, charts and diagrams for reports are generated automatically to the Lesotho Millennium Development Agency and private companies that are the hired through LMDA for record keeping and further to display and store the information meant for additional investigations and improvements.

Collection and removal of trash is done in timely manner, truck drivers are able to have scheduled work and planned route. This system is meant to make waste management, more efficient and effective, less costly and it saves time. The advantage of the system to other smart waste management’s systems is that the system uses excel to receive real-time data, there is no need for internet usage which means extra savings. Without internet usage all problems associated with internet usage are avoided.

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Chapter 1: Introduction

1.1 Introduction

Lesotho as a developing country experiencing high urbanization. People migrate from country side areas of Lesotho to the cities especially Maseru, the capital town of Lesotho in search for jobs as a result the population in Maseru is growing at a very vast pace. Maseru has the highest population compared to other districts. The population is approximately 118,355.

Due to a population increase in Maseru, there is also a high chance of increased waste generated. We live in the world where we use all sorts of materials that need to be thrown away at any point in time every day and we throw them away every second of every day. It is an individual right to have a clean and healthy environment. Therefore it is mandatory to have people responsible for waste management in a country.

Waste collection and disposal is a high demand concern. Waste bins are also a growing concern, for better waste management, the bins must be populated all over the commercial, residential, institutional and Hospitals and real-time collection and disposal. This keeps the environment clean and healthy place to avoid illness that may be caused by unhygienic conditions. In order to meet this need, Lesotho needs to adopt a smart waste management system like any other developing countries.

This paper focuses on smart waste management at Queen II hospitals. The trash bins need to be collected on a timely basis before they overflow with trash making the environment dirty, but unfortunately that does not happen with the traditional method of collecting and disposal of trash. The trash bins get filled with trash, reach maximum level until the trash overflows and is scattered all over the place, polluting the environment, producing bad odor, unclean, unhealthy and unhygienic conditions.

The private trash companies are hired under the LMMA umbrella to collect the hospital and healthcare Centre trash bins. Due to the problems caused by traditional method of trash collection mentioned above, a smart trash bin (STB) management system needs to be implemented.

A new improved method whereby the general waste collectors will have prior data in regards to the bin's status before trash overflows and trash is scattered all over the ground. The bins will then be collected on a timely basis before the bins overflow with trash. Furthermore the bins will have a unique identification to be able to distinguish General waste bin to hazardous waste bin. There is a minimal risk if waste collector have bin identifications with labelling as general waste or hazardous waste.

The proposed solution introduces the concept of Smart bin, the smart bin is connected with the ultrasonic sensor to sense the closeness of an obstacle from the bin lid to the sensor. The information is received in real time. This information is logged on to excel sheet to organize, manipulate and analyze the information to assist in future planning of real time collection and disposal of waste. The solution makes it easy for the collectors to choose their collection days accordingly based on the information projected on the screen of the computer. Smart Trash Bin is a solution to smart monitoring of waste collection and priority can be given to areas that need most attention due to their high level of filled bins.

1.2 Background study

Research has shown that Internet of Things is an area that is being applied in our daily lives. Every object can be connected to the internet and given an identifiable number on the internet for easy monitoring and controlling of those objects. All this is attained by means of application of sensors.

“The Internet of Things (IoT) is an umbrella concept depicting the inter-networking of physical devices, vehicles, buildings, and other items embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data” mentioned (Stanislas, 2018).

“Nowadays, cities with developing economies experience exhausted waste collection services, inadequately managed and uncontrolled dumpsites and the problems are worsening. Waste collection method in such countries is an on-going challenge and many struggle due to weak institutions and rapid urbanization” states (Shamlee, et al., 2017).

(Indu, et al., 2017) Also maintains “All the equipment’s we use in our day to day life can be controlled and monitored using the IOT. A majority of process is done with the help of sensors in IOT”. As such, a smart waste management is being implemented in smart cities and some of developed countries, with most undeveloped countries still following the old traditional method of waste collection.

According to (Nagajothi, et al., 2018) “the smart garbage management system makes the garbage collection more efficient the use of solar panels in such systems may reduce the energy consumption”. To put more emphasis (Navghane, et al., 2016) Adds “Sensors are deployed everywhere and these sensors convert raw physical data into digital signals and transmits them to its control center. These dust bin model can be applied to any of the smart cities around the world. By this way we can monitor environment changes remotely from any part of the world via internet”.

1.3 Problem Definition

The general waste collectors do their collection ones a week at Healthcare Centers and two days a week at Hospitals. Even with their scheduled days, the current state of the Hospital and healthcare facilities still face issues of trash bins that overflow before collection time. Trash bins overflow pose risks of unhealthy and unclean environment.

Issues of under filled waste bins on collection time. This leads to un-optimized truck routes that cause high fuel usage and fuel emission that pollutes the air. The time is wasted and a there is an increase in unnecessary costs.

The plastic bin liners provided to the healthcare centers are misused. They are not used efficiently as they are supposed to. Misused bin liners are the ones that are not filled to the required level. This is poses a concern to the private company that provides them. The general waste mixed with hazardous waste that complicates collection due to the fact that general waste collectors are not supposed to collect and dispose hazardous waste due to health risks.

1.4 Purposes of the study

The purpose of this project is to ensure effective management of general waste from point of generation to point of disposal. This is facilitated through consistently supplying healthcare facilities with plastic liners, which are being collected once a week from each Health Care Facility and twice for Hospitals, and finally transporting the waste to the designated disposal site.

This is achieved through real time reports to the concerned authorities. This is based on the fact that the prior information is projected on the excel spreadsheet about the status of the bin. This ensures the trash is collected on scheduled time reducing unnecessary fuel cost. To keep the environment clean and healthy. Generated also help to predict and plan the future of smart waste management.

1.5 Research Objectives

- In the proposed system trash pickup is an automated process; optimized and better managed as a result we will have uncontaminated and healthy surroundings.
- In the proposed system the evaluation and impact of providing information about the expected pickup bin collection days result in mitigating scattered waste.
- In a proposed system each trash bin will be interfaced with a sensor for calculating the volume or percentage of trash in the bin.
- In a proposed system Excel will provide the continual access to real time information about percentage of trash inside the bin will help waste collectors to plan their daily or weekly pickup schedule to save time and unnecessary costs of fuel usage.

1.6 Research Questions

- What method of waste collection and disposal is currently operational in the Hospitals?
- How effective is the current method of waste collection?
- What issues are faced with the current system?
- What is being done to address these issues, or how are the people responsible addressing the issues?
- How can the current system be improved to try to alleviate some if not all the issues?

1.7 Solution

To solve issues of overflow of bins, an ultrasonic sensor is used to measure the distance of trash bins by using sound waves. Use an Arduino UNO to send real-time data to excel spreadsheet. The information is received in real-time to the control center of the collectors. This smart waste collection assist collectors have a scheduled work plan. With that there is less fuel consumption that in turn save costs and there is less time travelling to and from the collection site while the bins are not full.

A more effective method of educating and training people responsible for collection and disposal of general waste and hazardous waste will be conducted. The system ensures that hospital people know the fill level of each bin. This information will be made known to all parties involved.

The information generated from the excel spreadsheet ensures prior information to the status of the bin. This ensures that the bins are collected on time. trash collectors at the respective hospitals and healthcare systems to continually use the spreadsheet in their work place control room to have access to, and observe the amount of trash in the bin on a daily basis before the disposal of each collection to get acquainted with which trash bins are full and which are not to make sure to dispose the trash in the appropriate bin with the low fill level.

All these solutions will help predict the next fill level or monitor the areas that need to be given prevalence over areas that do not have the highest rate of fill level. This priorities can be in the

form of increasing the number of dustbins, increasing the number of collection date on area that need them most. All these projected solutions will be incorporated in next year of funding.

An excel spreadsheet is used to collect the data from the smart trash. The information is organized, manipulated with complex functions. Turned into charts and graphs for easy reporting on a monthly basis to Lesotho Millennium Development Agency (LMDA), and the trash collecting company as a whole. The data is analyzed to make forecasting prediction and help plan the future.

Chapter 2: Literature Review

2.1 Introduction

The study focuses on theoretical review and empirical review of waste management based on analysis from different journals, scholarly articles, conferences, books and research papers. The analysis is made on the existing models and solution of smart waste systems, optimized route algorithms to save time and cost on fuel consumptions and how IoT enabling technologies are employed in smart waste systems.

2.2 Theoretical Review

The theoretical studies justifies the use of smart waste management that, at present exist, how these theories relate to each other and to what extent the current theories have been studied. Development of new theories, prototypes, frameworks and models and the ones that are to be tried. The review is based on the themes of this project.

2.2.1 Introduction

This literature review focuses on what is waste, the management of these waste, issues caused by poor management of waste and how the smart waste management came to the rescue. According to (Chavan & Pattanshetti, 2018) “Waste management includes planning, collection, transport, treatment, recycle and disposal monitoring and regulation of waste”.

Excess waste in urban areas is due to too many people move from countryside to the towns and cities in search of work and better life, increase in population, results in the high rate of waste being disposed, hence the need for efficient waste management system. These issues related to waste management include trash bins spilling over, the scattered waste in public places, the pollution of air and land, health problems that are encountered with spreading of diseases from waste, the issues of time of collection of these bins are all major concerns to the public.

To put more emphasis (Aruna & Priya, 2018) Mentions that the municipality or authorized collectors receive the information late because too many times the dustbins are seen spilling over and this results in unhygienic condition on the environment, air and land pollution. Also that there is lack of monitoring of waste level hence waste collectors waste a lot of precious time with unnecessary visits to each end every bin in different locations to find out if the trash in the bin is full . (Satyamanikanta & Narayanan, 2017) Add “The waste is overflowing from the bins and finally it leads a situation of general bin into mini dump yard in each and every street. So, it’s became a major problem for the municipal authorities to clean that waste. They are unable to clean that waste in time. So, to reduce this, based on latest technology moving to smart bins”.

According to (Chavan & Pattanshetti, 2018) The waste filling up to a point of spilling over the surface and making the environment dirty is because the authorities are not providing enough care and consideration. All these issues of waste management are worldwide (Chavan & Pattanshetti, 2018) add “At present waste management is a major concern in the metropolitan cities of the developing and developed countries”. “In Indian cities, waste management is mainly handled municipal committees” (Pokalekar, et al., 2018) “In cities waste management became a particular problem because most of the people living in cities and in future number may increase, because of this over population in cities many problems are arising like pollution, waste management” (Satyamanikanta & Narayanan, 2017).

“In a Smart City, waste collection is a vital point for environment and its quality should be considered seriously. Fundamental components of smart city are Smart Economy, Smart Environment, Smart People, Smart Living, Smart Mobility and Smart Governance. Smart Environment is the major fundamental component which is tightly connected to environmental pollution.” (Aruna & Priya, 2018).

Smart waste management system uses the concept of IoT, waste bins and the programmed sensors to detect the distance of waste inside the bins. All these studies are due to an increase in urbanization, there is also a high rate of waste production. Therefore better and more efficient waste management systems are development are a must have to mitigate waste in various places.

While smart cities have since adopted the idea of smart waste management system, developing countries are slowly adopting the idea.

2.2.2 Existing smart waste bins solutions and models

The following studies discuss about the existing solutions, models and methods applied to smart waste management systems. Different studies have developed model and solutions to waste management, either collection, disposal or recycling and all of the have evidenced to be effective in delivering the information needed. The solutions and models uses IoT and enabling technologies such as sensors, microcontrollers, Wi-Fi modules, GPSs and RGPSs.

These solutions and models are meant to resolve all problems encountered with the traditional methods of waste collection. The level of waste is monitored on a timely basis and if the waste reaches the maximum level, the results are send to the authorities in time to make collections before the bins start to spill. The location of the bind is also send to the authorities in an effort to save time and money with unnecessary visits to bins that are not full.

The waste (Nagajothi, et al., 2018) Suggested implementing Sensor Based Waste Collection Bins will circumvent waste overflow and scattering all over the place from the waste bins. The bin is programmed to check the waste level and the information will be send in real-time to the truck driver responsible for collection.

The proposed system is “a Sensor Based Waste Collection Bin. It is a Real time waste management system that would keep checking the bin status and the results can be accessed by the trash collector in real-time. The sensors used are the Gas sensor to sense the change in the exhaust smell and smoke and that signal is in analog form and ultrasonic sensor which intimates about the load placed on it. As a result of this real-time data the objectives of the study: resource optimization, cost reduction, effective usage of smart dustbins as” mentions (Nagajothi, et al., 2018).

(Nagajothi, et al., 2018) Adds “The technologies which are used in the proposed system are good enough to ensure the practical and perfect for solid garbage collection process monitoring and

management for green environment”. Implementing such system that use IoT in smart waste management system can and will help avoid trash overflow at all cost. The scattered waste is alleviated, the environment becomes clean and healthy.

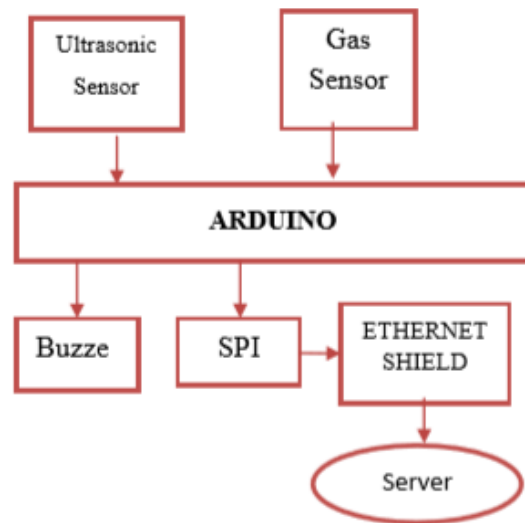


Figure 2-1: Block diagram (Nagajothi, et al., 2018).

(Prasanna, 2017) Focused on the necessity for Smart Bin maintaining that unhygienic conditions caused by overflow of trash all over the place is a concern to the public. Therefore in the paper (Prasanna, 2017) proposed “the smart bins will be installed at sub- terrestrial level integrated with smart microcontroller, load cell, compacter and IR system. Every smart bin is provided with specific identification. The compacter is used to compress the unnecessary garbage in the bin”.

The idea here is so that when the bin is about to get full then the message carrying the identification and location of the bin will be send to the control unit as soon as the sensor is triggered. The focus is based on Bio Medical Waste, Agricultural Waste and Industrial Waste (Prasanna, 2017).

(Anoop, et al., 2017) With IOT based Smart Waste Management ensures the bins do not pass beyond the fill level. The system processes will all be in real-time basis received by the Wi-Fi module from the Arduino’s microcontroller, to the hand held device using an android application. “The system processes will all be in real-time basis received by the Wi-Fi module from the Arduino’s microcontroller, to the hand held device using an android application” mentions (Anoop, et al., 2017).

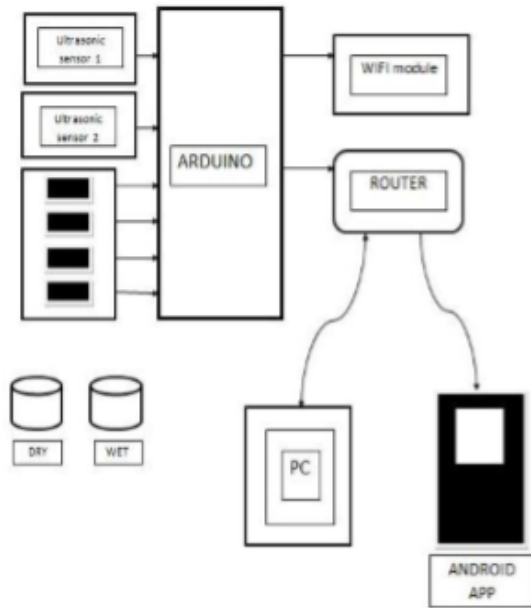


Figure 2-2: Proposed System Architecture (Anoop, et al., 2017)

(Jane & Bagherwal, 2017) Discusses a system whereby any person with a handheld android device can have a copy of the application and monitor the waste. The system uses “Ultrasonic sensor, force sensor, GPS, GPRS, LCD, Amazon cloud web server and Android application. The dustbin is placed with various sensors called ultrasonic sensor and force sensor” (Jane & Bagherwal, 2017).

“The ultrasonic sensor is used to check the level of the dustbin and force sensor is used to check the weight of the bins. When the value exceeds the threshold value, this information with the GPS location where the dustbin is located will be sent to server through GSM/GPRS system. The android mobile will fetch the information from the server in which area the dustbin is located by comparing the coordinates” (Jane & Bagherwal, 2017).

(Navghane, et al., 2016) Proposed “IoT Based Smart Garbage and Waste Collection Bin. The system using IR sensor, microcontroller and Wi-Fi module”. The waste collection bin system guarantees the trash bins is emptied on time by sending to the concern people and If not collected and disposed in time, the system reports to the control center hence action taken against the misconduct of the trash collector.

With these system there are none unnecessary trips whatsoever, thus the number of visits to the collection side is greatly reduced as a result there is less mileage to trucks. “The smart garbage management system makes the garbage collection more efficient” argues (Navghane, et al., 2016). (Nagajothi, et al., 2018) Stated “Our idea of Smart Waste Management System mainly focuses on monitoring the waste management, providing a smart technology for waste management system, by this reducing human time and effort, cost and which results in healthy environment”.

(Pokalekar, et al., 2018) Propose the system that keeps track of position of waste in the bin. Notifies the responsible collectors of the amount in percentage of waste in in the bin. To measure the waste level the proximity ultrasonic sensor is used, the bin level is acceptable if it is 0 to 70 percent. Beyond the 70 percent it means the bin is about to reach the collection state therefore the Wi-Fi ESP8266 01 module will receive the results about the status of the bin from the Arduino and stores them. The webpage server displays the status and location of all bins that needs to be cleaned. Then the GSM module send the SMS to the hand held devices of the waste collectors. The below diagram illustrates the operation of the system.

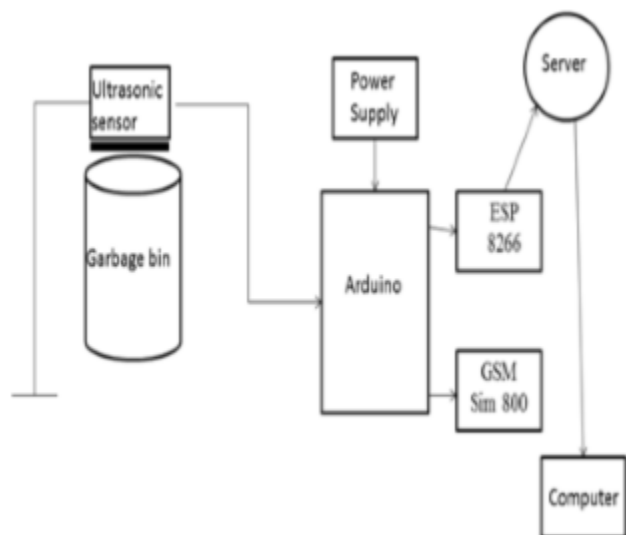


Figure 2-3: Block Diagram (Pokalekar, et al., 2018)

(Tambare & Venkatachalam, 2016) Proposed a system, a bin is interfaced with microcontroller, IR Sensors and RF module. “The dustbins are provided with low cost embedded device which will assist to keep track the level of the trash bins and a unique ID will be provided for every dustbin in the city so that it is easy to identify which garbage bin is full and immediate cleaning can be

done for healthy and hygienic environment” (Tambare & Venkatachalam, 2016). (Tambare & Venkatachalam, 2016) Further mentions “the status of the Garbage in the dustbin on the GUI on the web browser”.

The proposed system results are sending and receiving data in real-time data. The information is read all the time regardless the user’s location. Wireless Data transit to the recipient and lastly the sensor is able to measure the distance of trash. (Tambare & Venkatachalam, 2016). “The Block diagram shows the different component used in the Smart Dust bin System. IR Sensor, 8051 microcontroller, Power Supply, RF Transmitter, RF Receiver, Intel Galileo microcontroller and the web browser” (Tambare & Venkatachalam, 2016).



Figure 2-4: Block Diagram of the proposed System, (Tambare & Venkatachalam, 2016).

Urban areas with a high rate of population lead to high waste generation, piles and piles of waste is scattered all over the place with inadequate bins over filling and not cleaned in time. (Himadri, et al., 2017) Manage both hazardous and non-hazardous waste. Concerned that if waste is not cleaned and disposed in an efficient manner it’s a breeding ground for unpleasant consequences to urban environment, pollution to land and air, and unhygienic conditions affecting our health in general. “Their motivation is to provide an understanding of the various kinds of waste, and the required focus to improve our systems to enable the sustainability of the waste management sector with participation from both the government and private agencies” (Himadri, et al., 2017).

(Himadri, et al., 2017) Suggests “Waste collection today is inefficiently performed using static routes and schedules. Some bins are overflowing with waste causing unnecessary clean-up costs. This type of inefficiency wastes both time and money and is harmful for the environment but what

if there is a better way. Integrated hardware and software solution optimizes waste collection, saving time, money and the environment”.



Figure 2-5: IoTBase Smart Solution, (Himadri, et al., 2017).

(Himadri, et al., 2017) Review different strategies to waste management currently active in the municipality’s waste management system. (Himadri, et al., 2017) Stated “Every strategy is separated into a number of modules. Those are- reduction and employ, animal feeding, recycling, composting, fermentation, landfills, burning and land application”.

For example, in the study (Himadri, et al., 2017) points out that landfills are the most popular strategy to waste management, after collection, disposal is thrown into the landfills in an effort to conceal the dirt to prevent bad smell but unfortunately due to small land landfills pollutes environment. Choosing the right method is a resolution to having clean, hygiene, healthy environment to all.

(Shamlee, et al., 2017) Proposed a smart garbage alert system for efficient waste control designed to send a warning sign to the municipal web server for waste to be emptied immediately out of waste bins using prior data given attaining to level of the waste. The overall objectives of the smart bin is massive reduction on fuel cost and minimal air and land pollution to urban areas and to achieve a real-time 24-hour system with a real-time monitoring central system.

The circuitry diagram uses the ESP8266, HC-SR04 ultrasonic sensor are interfaced with the Arduino board. ESP8266 is made ready for the information to be read from the ultrasonic sensor and displayed on the HTML page accessed by the municipality.

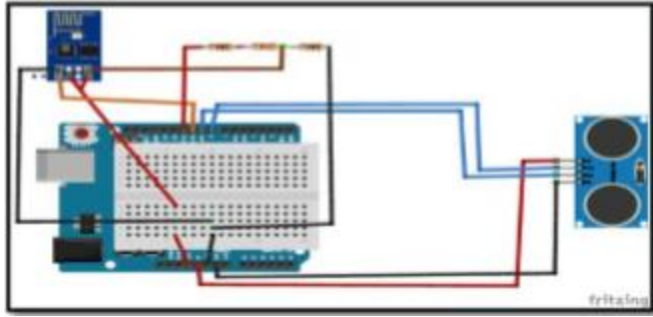


Figure 2-6: Implemented circuit (Shamlee, et al., 2017).

(Shamlee, et al., 2017) Concludes “As we can observe the system is designed to indicate us that whether the trash can is empty or full through the web server and we can know the status of the ‘Trash Can’ or ‘Dumpsters’ from anywhere in the world over the Internet. It will be very useful and can be installed in the Trash Cans at public places as well as at home”. (Shraddha, et al., 2017) Proposes a solution to frequency of dustbin cleaning with a Smart Garbage Bin, which uses GSM technology, Ultrasonic sensor and GPS application. When the garbage bin is about to fill an alert message is send to the authorized person.

(Fady E, 2017) Proposed “An intelligent waste container for small-scale cases, a system which will store usage events, recorded by PIR sensor, and fullness events on a memory card, which is also used to play audio message using a speaker, when the bin is being used. The system is based on Arduino Nano board and an ultrasonic sensor to monitor the fullness level of the container and give SMS alerts using a GSM module”. (Stanislas, 2018) Mentioned “Waste management includes various steps such as prevention, collection, recycling, reuse, and disposal of toxic waste and further Advocates dynamic and integrative models which would amount to transforming trash into cash by addition value to waste”.

(Singh, et al., 2016) “The proposed framework is a 3 tier system namely: Intelligent Bin, Gateway and Remote Base station”. (Singh, et al., 2016) Further mentioned that the framework uses accelerometer to monitor the lid as automatically opens when someone comes close and automatically closes when it does not sense any close object, ultrasonic, temperature sensors. Zigbee Pro is a source that communicate the information collected to the gateway. Lastly an application that provides a graphical user interface (GUI) for user interaction with the system is provided by the web server.

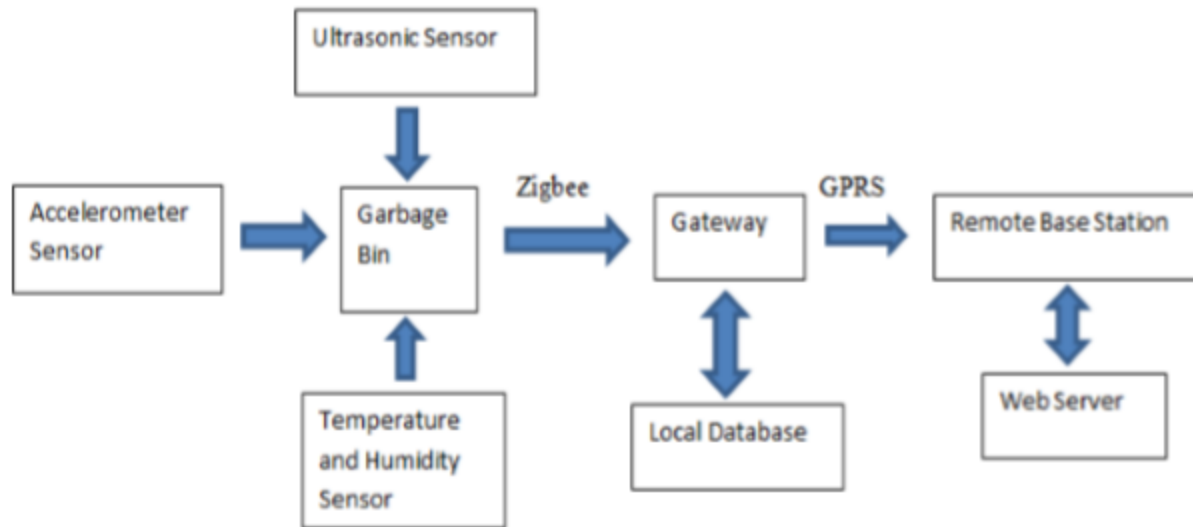


Figure 2-7: Block Diagram (Singh, et al., 2016).

(Thota, et al., 2018) Proposes “Smart Trash Can Monitoring System which detects the level of trash can and states whether it is empty or full through the mobile app and we can get to know the status of the Smart Trash Can from anywhere in the world via Internet. It is useful and can be fixed in the trash cans at public places, smart cities and other spots. We are using micro controllers and sensors to reduce the cost and to make it as an efficient device”. Same as most studies (Thota, et al., 2018) suggests that to check the level of the trash cans, the sensors are connected to trash can to sense closeness of the trash in the bin. “The sensors used are Ultrasonic sensor, Arduino Uno, GPS and Node MCU ESP8266 Wi-Fi module” (Thota, et al., 2018).

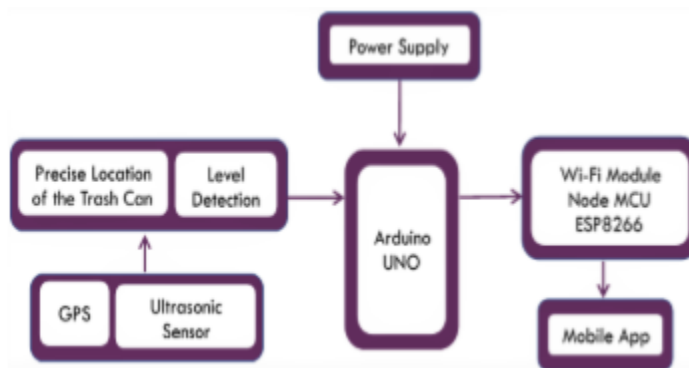


Figure 2-8: Basic Block Diagram (Thota, et al., 2018)

According to (Channe, et al., 2018) “The IOT Garbage Monitoring system is a very innovative system which will help to keep the cities clean. This system monitors the garbage bins and informs about the level of garbage collected in the garbage bins via a web page. For this the system uses ultrasonic sensors placed over the bins to detect the garbage level and compare it with the garbage bins depth. The system makes use of Arduino family microcontroller”. This system will help to diminish issues related to trash removal and help to keep the city clean.

(Channe, et al., 2018) “In this system an Ultrasonic Sensor is used for detecting whether the trash can is filled with garbage or not and will measure the distance of garbage from the top of trash can and we can set a threshold value according to the size of trash can. We will use ESP8266 Wi-Fi module for connecting the Arduino to the web server. Here we have used local web server to demonstrate the working of this Garbage Monitoring System. This system monitoring the garbage bins and informs about the level of garbage collected in the garbage bins via a web page”.

“The system makes use Arduino, LCD screen, Wi-Fi modem for sending data The LCD screen is used to display status of the level of garbage collected in the bins. Where the web page is built to show the status of user monitoring it. The web page gives a graphic view of the garbage level. Thus this system helps to keep the city clean by informing about the garbage levels of the bins by providing graphical image of the bins via IoT Pup web development platform” (Channe, et al., 2018).

(Satyamanikanta & Narayanan, 2017) Shows how the proposed system works, “if the person coming to throw the waste into the bin RFID card reader read the information stored in the tag. Photo electric sensor detects the clear detection of the object and sends the outline representation of object to the local authorities if is there any electrical components present inside the bin. Weight sensor detects the weight of the garbage present in the bin and with the help of RFID and IR sends the up to date information to the officers”.

(Singh, et al., 2016) “The sensor node attached to the bin helps in the collection and transmission of data. The sensor node is divided in 2 groups. The first group consists of accelerometer sensor, temperature and humidity sensor, ultrasonic sensor. The Accelerometer sensor checks the opening/

closing of the lid. The temperature and humidity sensor keeps track of the temperature and humidity inside the bin; two parameters that become important when storing organic waste. The ultrasonic sensor measures the filling of the bin”.

“The second group consists of a Zigbee Pro that acts as a transmitter to send the collected data to the gateway. The importance of this bin is that it can be used to store any waste: Plastic waste, E-waste, Metal waste, Food waste, Organic waste as in all these types of waste, collection interval will depend on the filling of the bin except in food waste and organic waste where all these parameters decide the collection interval” (Singh, et al., 2016).

“The Block diagram shows the arrangement of different components used in the Smart trash can system. Ultrasonic Sensor, Arduino Uno, Power Supply, Node MCU Wi-Fi module- ESP8266 for connecting to internet. The project module is divided into two parts sensor section and Node MCU Wi-Fi module ESP8266 section. Sensors are attached to the trash can. Sensors are used to detect the level in the trashcan whether it is full or empty” (Thota, et al., 2018).

“The sensor senses the content of the trash can and sends the signals or the data to the Arduino. Wi-Fi Module helps us to send the information of the trash can at the receiver side through internet. In this project the ultrasonic sensor will send the distance to Node MCU Wi-Fi Module ESP8266 and if the distance is less than threshold values it will send an alert message or notification to the concerned authorities or users” (Thota, et al., 2018).

(Channe, et al., 2018) “In solid waste monitoring system garbage been set the public place then Camera set for garbage bin location. The camera captured image for garbage bin. Radio Frequency Identification (RFID), GPS and GIS send image for work station. The RFID reader and camera are mounted in the truck, when truck comes closer to the bin RFID reader communicated RFID tag. & send all information. The control station compiled all the information and stored in the system database. The bin status and waste truck was monitored”.

(Channe, et al., 2018) “Develop an affordable and efficient method that can support to sort the dry and wet garbage. In this the new innovation is that we use the Internet of Things from this we can monitor our system from anywhere using internet of thing. If we use this system in our home then the wet and dry garbage is separated from our houses this is the vital role plays in this system”.

“Further, a wireless interface has been provided to control the system wirelessly and keep the cities clean from unhygienic and hazardous environments. The technologies which are used in the proposed system are good enough to ensure the practical and perfect for solid garbage collection process monitoring and management for green environment” (Channe, et al., 2018).

“In this waste collection system the waste level is measured by an ultrasonic sensor. From the top of the bin the sensor calculates the distance between the trash and its transmitter. This sensed data is sent to the Node MCU which has an Arduino like hardware and ESP8266 Wi-Fi module. Bins are equipped with GPS receivers to obtain the locations where they are placed. These obtained locations are sent to the Node MCU” (Channe, et al., 2018).

By using optimized selection algorithm, daily best routes are calculated and their locations are sent to the drivers using GSM modem Sim 900A which is connected to the Node MCU. The entire received bin data are also sent to the site called WWW.ALLTHINGSTALK.COM, where the bin level is observed and also the graphical approach can be noticed. The programming of Node MCU is done in Arduino IDE” (Aruna & Priya, 2018).

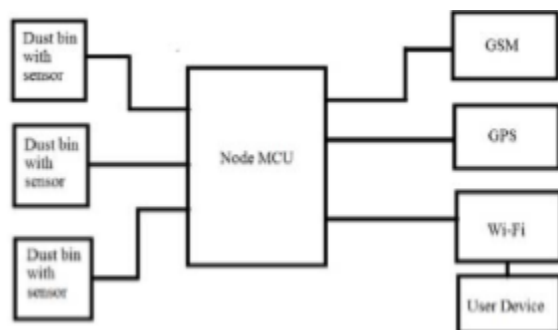


Figure 2-9: Smart Waste Collection System Architecture (Aruna & Priya, 2018).

Most but not all of the authors in the previously mentioned studies, their models and solutions have all proved to be cost effective and efficiently employed. The sensors used provide real-time data on users' mobile phones and web sites to minimize dustbin overflow and provide optimized routes, but however the short comings of these models are examining and clarification of the results.

The author (Channe, et al., 2018) however includes the database in the model to store the data, which makes these model different from all other models while (Aruna & Priya, 2018) specializes with a web site called www.allthingstalk.com to graphically display the results for analysis and interpretations of future work. The data should be used somehow to analyze the results. The question at hand is how the models can incorporate means of data storage and analysis for future predictions.

2.2.3 IoT technologies in smart waste management systems

The IoT enabling technologies interfaced into objects makes these objects smart. The object can sense all things around us. This makes it possible the change the world in to a better place. These technologies include among others the GPS which is used to identify the location, the temperature, distance/proximity, humidity, optical, thermal sensors. Programmable circuitry boards that can be used to connect to the sensors and other input and or output devices including LCDs, LED motors, computers and other devices.

Waste management is assisted with these enabling technologies to develop smart waste bins that are able to detect when the bin is about to reach the maximum level, if the required level is reached the working bins send the information to receiving devices of the authorized collectors, if collections are made the information is updated.

IoT: According to (Satyamanikanta & Narayanan, 2017) “The Internet of Things (IoT) is a system of interrelated digital machines, devices objects, animals or people that are provided with separate identities and the ability to transfer data over a network without requiring a human-to communicate to the other -human or human-to-computer interaction”.

Infrared sensors: “Infrared sensors will be able to detect or emit IR radiations to scan the surrounding area. They are capable of amount of that the object emitting and they have the ability to detect the motion of the objects. All the objects which have a temperature greater than absolute zero possess thermal energy and sources of infrared radiation as a result” (Satyamanikanta & Narayanan, 2017).

Optical sensors “are widely used in automated systems because they have been available no longer and can fit into small locations. These are commonly known as light beam sensors. Explains (Satyamanikanta & Narayanan, 2017)”.

Proximity sensors: “A proximity sensors is a sensor able t to detect the presence of nearby objects without any physical contact. Its life time is long because of absence of mechanical parts” (Satyamanikanta & Narayanan, 2017).

Thermal and temperature sensors: “It is a device that converts the thermal quantity into some physical quantities such as mechanical energy, pressure and electrical signals” (Satyamanikanta & Narayanan, 2017).

Weight Sensor: “It is used to calculate the weight of the total waste percentage in the bin and sends the information to the authorities. It will show the up to date information to the authorities the level of garbage present in the bin” (Satyamanikanta & Narayanan, 2017).

Ultrasonic sensor: The ultrasonic sensor is used to degree of the closeness of space to an object by means of ultrasonic waves. (Pokalekar, et al., 2018) Explain “The sensor head emits an ultrasonic wave and receives the wave reflected back from the target. Ultrasonic Sensors measure the distance to the target by measuring the time between transmission and reception”. (Thota, et al., 2018) Mentions that the ultrasonic sensor measures the period between signals and their returns. “One of the advantages of ultrasonic sensing is its outstanding capability to sense deep details without any disturbance”.

The following pictures bins that are interfaced with different sensors which accomplishes different tasks.

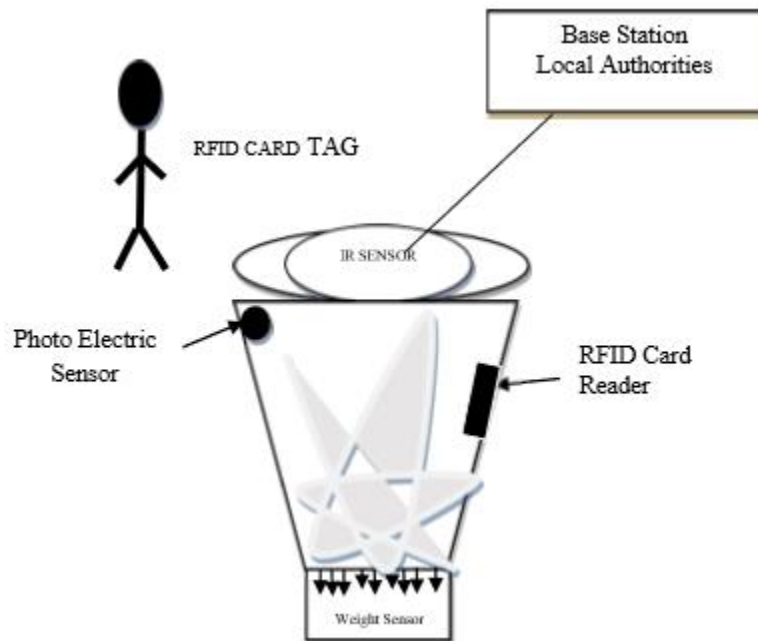


Figure 2-10: Smart Garbage Monitoring Architecture (Satyamanikanta & Narayanan, 2017).



Figure 2-11: Smart Dust Bin (Tambare & Venkatachalam, 2016).

The figure “shows that smart dustbin in which the IR sensor is deployed to detect the level of the dust inside the dustbin and 8051 microcontroller to read the IR sensor data and the RF transmitter module to transmit the dustbin level information to the central system” (Tambare & Venkatachalam, 2016).

Microcontroller: “Micro controller used is Node MCU. It has Arduino like hardware and ESP8266 Wi-Fi module. This microcontroller is used because it has combined features of Wi-Fi access point and microcontroller and is also less cost system on board for IoT projects. It uses LUA based programming language. It consists of 4MB storage and 128kb memory” (Aruna & Priya, 2018).

GSM (Global system for mobile communication): “GSM (Global system for mobile communication) is a digital mobile telephony system used in all world. GSM uses TDMA system” state (Pokalekar, et al., 2018). “It is a specialized type of modem which can accept a SIM card and it also operates like a mobile phone. The modulation used in this is Gaussian Minimum Phase Shift Keying (GMSK). It is a kind of continuous phase frequency shift keying. The transmission rate of a time slot is 22.8Kbps” (Aruna & Priya, 2018).

Radio frequency identification (RFID): (Satyamanikanta & Narayanan, 2017) Uses Radio frequency identification (RFID) reader to “takes the information from the person who wearing the RFID card tag it has some details stored in it .based on these it can send the notification to that particular person through notification like an appreciation message and notifying that what he dropped inside that bin”.

Photo electric sensors: “Photo electric sensors are used to detect the type of the objects which are coming inside the bin like metals or non-metals. It can detect the size and type of object by focusing a light on that. Through this the local authorities can get information if is there any electronics placed inside the bin they can immediately came to know about that. Using this sensor respected authority can see the clear outline representation of the object. So, by this information they can easily remove the electronics in the bin” (Satyamanikanta & Narayanan, 2017).

ESP 8266: “The ESP 8266 is a low power highly integrated microchip. It is mainly used in IOT based project because it consumes low power. ESP8266EX has been designed for mobile, wearable electronics and Internet of Things applications with the aim of achieving the lowest

power consumption with a combination of several proprietary techniques” (Pokalekar, et al., 2018).

GSM: GSM (Global system for mobile communication) “is a digital mobile telephony system used in all world. GSM uses TDMA system module. It is capable of receiving information from GPS satellite and then calculates the device geographical position” (Pokalekar, et al., 2018)

GPS Module: (Thota, et al., 2018) Mentioned “The Global Positioning System (GPS) is a satellite-based navigation system made up of at least 24 satellites. GPS works in any weather conditions, anywhere in the world, 24 hours a day. GPS receivers use this information and trilateration to calculate a user's exact location”.

(Aruna & Priya, 2018) Stated “Global positioning system (GPS) helps us to track the locations of objects and even individuals which have a GPS receiver. It has 3 segments namely, Space segment, User segment, Control segment. It transmits data in serial TTL format. GPS transmits information in the NMEA (National Marine Electronics Association) format, in which each sentence begins with a \$ symbol”.

User Device: User devices that are used to receive status and location of the bin include personal computers through cloud and or Wi-Fi module and user mobile phones or handheld devices through SMSs or mobile application. For example (Aruna & Priya, 2018) Explains “Drivers receive messages to their mobiles and the officials or the municipal authorities can observe the bin levels and the graphical output on ALLTHINGSTALK site using any device like mobile, laptop, tablet, PC”.

Arduino board: (Thota, et al., 2018) add “the Arduino board is the collection of digital and analog input-output pins. Arduino Uno is most popular board in Arduino family”. According to (Pokalekar, et al., 2018) “The Arduino board is the collection of digital and analog input-output pins. Arduino Uno is most popular board in Arduino family”. While (Thota, et al., 2018) add that Arduino “It’s a single-board microcontroller, designed to make the application of interactive objects or environments more accessible. Sense the environment by receiving input from variety of sensors. Can be programmed with the Arduino software IDE”.

Arduino IDE: “The Arduino IDE is a cross-platform, open source application that integrates a C++ code editor, the GNU C++ compiler, and a program upload utility” (Pololu Corporation, 2001–2019). “Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online” (Arduino, 2019).

“Arduino IDE is a programming platform for Arduino microcontrollers. Arduino IDE also supports Node MCU. “ESP8266 Core for the Arduino” is the developed Arduino core for ESP8266 Wi-Fi Soc. ESP8266 modules must be installed in to the Arduino library. The code written in the Arduino IDE is compiled and dumped in to the Node MCU using an USB cable” (Aruna & Priya, 2018).

2.3 Empirical Review

These case studies provides applications waste management to provide optimized routes and to try and alleviate high fuel consumption and minimize cost. The case studies include The Easy Clean System in Sri Lanka, a model that uses binary integer to manage the waste in the right manner In the Surakarta city, and a smart waste city management (SWCM) in Philadelphia city.

2.3.1 “Case study of Easy Clean – A Smart Solution for Garbage Finding and Collecting in Sri-Lanka” (Sharaaf, et al., 2017)

The case study of (Sharaaf, et al., 2017) Outlines uncondutive prevailing conditions in the traditional way of collecting waste in Sri Lanka. In an effort to keep Sri Lanka’s environment clean. The Easy Clean System is proposed. The Easy Clean System is an effective waste managing built on Internet of Things (IoT) per the objectives to eliminate or minimize the “unhygienic landfills, overflowing waste bins, limited collection, lack of storage in collection vehicles and less awareness of separated waste collection, recycling and reuse” (Sharaaf, et al., 2017).

The proposed system uses “various sensors such as load cell sensors, ultrasonic sensors and Global

Positioning System (GPS) module to track location and status of bins, GSM/GPRS shield for data transmission and Arduino MEGA 2560 to interface all the above hardware units” stated (Sharaaf, et al., 2017).

2.3.2 Case Study: Surakarta City Indonesia (Sutanto, et al., 2017)

“Garbage problem in Surakarta city is managed by three parties namely Environment Agency, market office, and district office. Garbage collected at the temporary dump, garbage from the street, and garbage from activities is managed by Environment Agencies. The Market Office manages the waste in the market, and household waste is managed by district office. Garbage from offices, hospital waste, and garbage from the business world is discharged directly to landfills in accordance with local regulation no 3 of 2010” explains (Sutanto, et al., 2017).

In the Surakarta city (Sutanto, et al., 2017) propose a waste management model that uses binary integer to manage the waste in the right manner. “The model optimizes waste transport by regulating the type of vehicle used to transport garbage at each landfill based on the distance travel by each vehicle, the maximum carrying capacity of the vehicle, and the maximum capacity of the landfill. The problem of garbage transportation investigated in the research is the market waste that exist in Surakarta City” (Sutanto, et al., 2017). The models are virtually made with MASIM (Material Simulation) technique that uses any logic program. There are two mathematical models of garbage transportation market namely, vehicle selection and vehicle route.

Previous studies have almost exclusively focused on route optimization. For example the model for vehicle route employed by (Sutanto, et al., 2017) is efficiently employed in to their system to optimized routes. This proved a usable advantage to this research hence the objectives are the same in minimizing the cost of fuel usage on travelling and save time on making unnecessary trips to check bins that are not full.

2.3.3 “Case study of Philadelphia city: A Waste City Management System for Smart Cities Applications” (Vu & Kaddoum, 2017).

(Vu & Kaddoum, 2017) Studies Philadelphia city “this paper presents a new method of smart waste city management which provides a clean and hygienic environment to the city resident. In this approach, the collected data from the trash bin has been transferred over the Internet to the server which contains the status of each bin”.

The contributions of the paper includes (Vu & Kaddoum, 2017) “number of working clusters in each city are clustered and the location of new trash bins are classified automatically. A regression algorithm is applied to predict the situation of waste which can avoid the overload trash phenomenon while the garbage truck is coming to gather the trash bins. The priority weight of each bin is considered to conduct the optimal garbage truck routes algorithm more efficiently”.

The objectives of the proposed model is to optimize truck routes. The bin is monitored and based on the prior information analysis of data is made so that the bin is collected on time. (Vu & Kaddoum, 2017) Add “Then the status of the bin is updated accordingly, which is the most important input parameter of optimal garbage truck routes algorithm”.

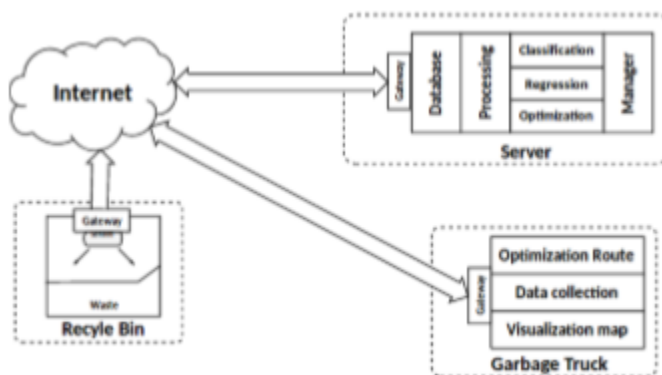


Figure 2-12: The smart waste management system overview (Vu & Kaddoum, 2017).

The study by (Vu & Kaddoum, 2017) rely on the internet for communication, the shortcoming of these is dependent on the network and data, if there is no network the system will not be able to send information to the responsible parties, hence we can have an on and of network that goes for days. This model can be improved by using another method that can bypass the network directly to the database or other device that does not require Wi-Fi usage.

(Aruna & Priya, 2018) Proposes “The data collected by sensors is sent to a server where it is stored in a database and processed. The collected data is then used for monitoring and optimizing the daily selection of trashcans to be collected, calculating the routes accordingly. The rate at which trashcans are being filled can be analyzed and the optimized selection of trashcans reduces the costs, improves the collection efficiency or both, depending on the predefined economic requirements” (Aruna & Priya, 2018).

(Aruna & Priya, 2018) Employed a database in to the system, where the data can be store and manipulated and monitored over time to make priority selection of waste collection, this make it easier to choose the area with the highest rate of pickups. In the light of the report, this research will use the PLX DAQ tool to store the results and use for future analysis and determining areas of priority based on the analysis made by excel overtime.

Previously mention case studies focused more on having a clean and healthy environment: The research is inspired by the use of a smart bin that leads to a clean and healthy environment. (Sharaaf, et al., 2017) “Case study has applied load cell sensors, ultrasonic sensors and Global Positioning System (GPS) module to track location and status of bins, GSM/GPRS shield for data transmission and Arduino MEGA 2560 to interface all the above hardware units”. This sensors has been used in other different studies as well. The motivation behind their studies to this research is that real-time information is received by the authorized collectors, waste collection is done on time, and no waste at any point in time will overflow the bins.

In the current case studies waste is mitigated to satisfy the requirements of keeping the environment trash free. The studies find different ways to mitigate the most challenging issues of waste management. The improved waste collection models presented minimize the overflow of waste and waste scattering is mitigated with the use enabling technologies with real time information from interfaced sensors.

The study makes use of the smart waste management system. Inspired by the effectiveness of the ultrasonic sensor, the popularity and ease of use of the Arduino from (Anoop, et al., 2017) (Aruna

& Priya, 2018) (Channe, et al., 2018) and other previous studies. The ultrasonic sensor will be interfaced with the Arduino on the solderless bread board, with the exception that other than using the Wi-Fi module and mobile phones as receiving devices. The system will basically be the Arduino to excel communication. This will have an added advantage to making real-time reports for the authorities and further make predictions and priorities of collection days.

In conclusion, the strengths of the smart waste management systems studied above are dependent on the use of proximity sensors to prevent bins from overflowing. Alleviating scattered waste, preventing pollution and bad odor, unhygienic, unclean and unhealthy condition and to save time and cost fuel consumption based on the idea that the process is automated. Automated process is sending real time information about the level of trash in the bin to the authorized people then the bins are cleaned in a short period of time to avoid over spilling of waste.

The research's solution and model is in the choice of using Arduino Uno circuitry board and the Ultrasonic sensor for distance measure and personal device as the receiving information device. The research's model is best in applications of waste management such as automated waste collection, route optimization and mitigation of scattered waste. Advantages of the ultrasonic sensor in my proposed system, is waste collection is an automated process, the bin shares the status of the bin from time to time, with these prior information prior arrangements are made in time to collect the bin if the bin reaches the maximum level.

An automated waste pickup is an automated process that ensures that there is no physical checking of the bins. Real time information is provided by a smart bin. The ultrasonic sensor is a distance sensors that will detect the fill level in the bin, and the information can be send through to Arduino to excel communication, with smart phones, computers, as preferred receiving devices. This is best communication since the smart bin does not require Wi-Fi for the information to be send. Therefore the Bin assist in automated waste collection to have a better managed waste pickup with SMSs or messages send to the excel control center for immediate pickup.

The most important part of optimized route is saving time on unnecessary visits to unfilled bins and costs on fuel consumption. The concept is achieved through communication between the ultrasonic sensors and concerned authorities: this means that when the bin reaches the fill level a communication is made to the receiving parts. This ensures that waste collection is done only the bin have reached the fill level. This help truck drivers to plan their pickup schedule and plan their routes to minimize the usage of fuel. Air pollution also greatly reduced hence the trucks only move at collection points only when is necessary.

Chapter 3: Research Methodology

3.1 Introduction

Following the literature review, the working models and solutions of the previous studies, the study uses the literature as a useful background in to this chapter. This chapter explains research methodology entire process step by step, how to successfully embark on the study through to the completion. To have a clearer picture of the study, the who's, what's, why's and how's of the study will also be clarified in more detail, that is: the research design, method, approach applied, instruments used for data gathering, analyzing data, population and sampling, data analysis procedure, the ethical considerations and indicate what limitations are encountered during the research.

This chapter is sectioned into three approaches. The first will be the qualitative approach. This approach will use structured questionnaires to gather the required information from the respondents based directly into the users' insight ideas and observations on the waste management. The other approach will be quantitative approach. This approach will basically focus on the researcher observations on status of the bins.

3.2 The proposed system

In an application of IoT, the smart trash bin ensures the continued monitoring of the waste by measuring the level of waste in the bin. This is achieved through the use of an ultrasonic sensors interfaced in the smart bin which is the one responsible for measuring the volume and percentage of waste and sending the data into the Arduino Uno. The Arduino Uno upon receiving the information sends the data directly to the Excel through the PLX-DAX Parallax acquisition tool for Microsoft tool which is responsible sending data in real time on to the authorities monitoring the Arduino to Excel communication on to the computers in the control room of the responsible collection company and that of the Lesotho Millennium Development Agency (LMDA).

This is done mostly to make sure that the data, the collections, and the reports are not forged. The results are also meant to keep records of the results in the form of graphs and also to use

those projected graphs to predict the priority of the bins that have the highest fill rate. The data, the received results are used mainly to check the status on the bin, and also to predict the next bin to reach the fill level. Once the bin is filled to the required level the control room officials make sure that the bins are emptied on time to avoid the bins over spilling. The advantage here is that the authorities are able to check if the bins are cleaned or not

3.3 Research Setting

The location of the study will be Queen II Hospital Maseru Lesotho. This is where the data will be collected. Previous related studies exists that discussed the smart waste management system proposed, developed and employed in smart cities and in some developing countries, therefore the research will use literature review and for the reason that for this part of the country and the city as well the is none related study whatsoever, the researcher will use own observations on the study area the interviews and also the Questionnaires on the selected sample.

3.4 Qualitative Approach

The researcher focused on study designs in qualitative research. Qualitative data deals only with non-numerical data. “In qualitative research the focus is on what should be the basis of analysis obtained; that is its contents, disclosure. Narrative or even analysis” stated (Kumar, 2011).

3.4.1 Research Design

Research design is a qualitative study (Las Das, 2005) defines the research design as the “researcher’s overall for answering the research question or testing the research hypothesis”: That is the researcher will embark on the design to make sure that the evidence collected allows the research to provide solutions to questions and to assess theories.

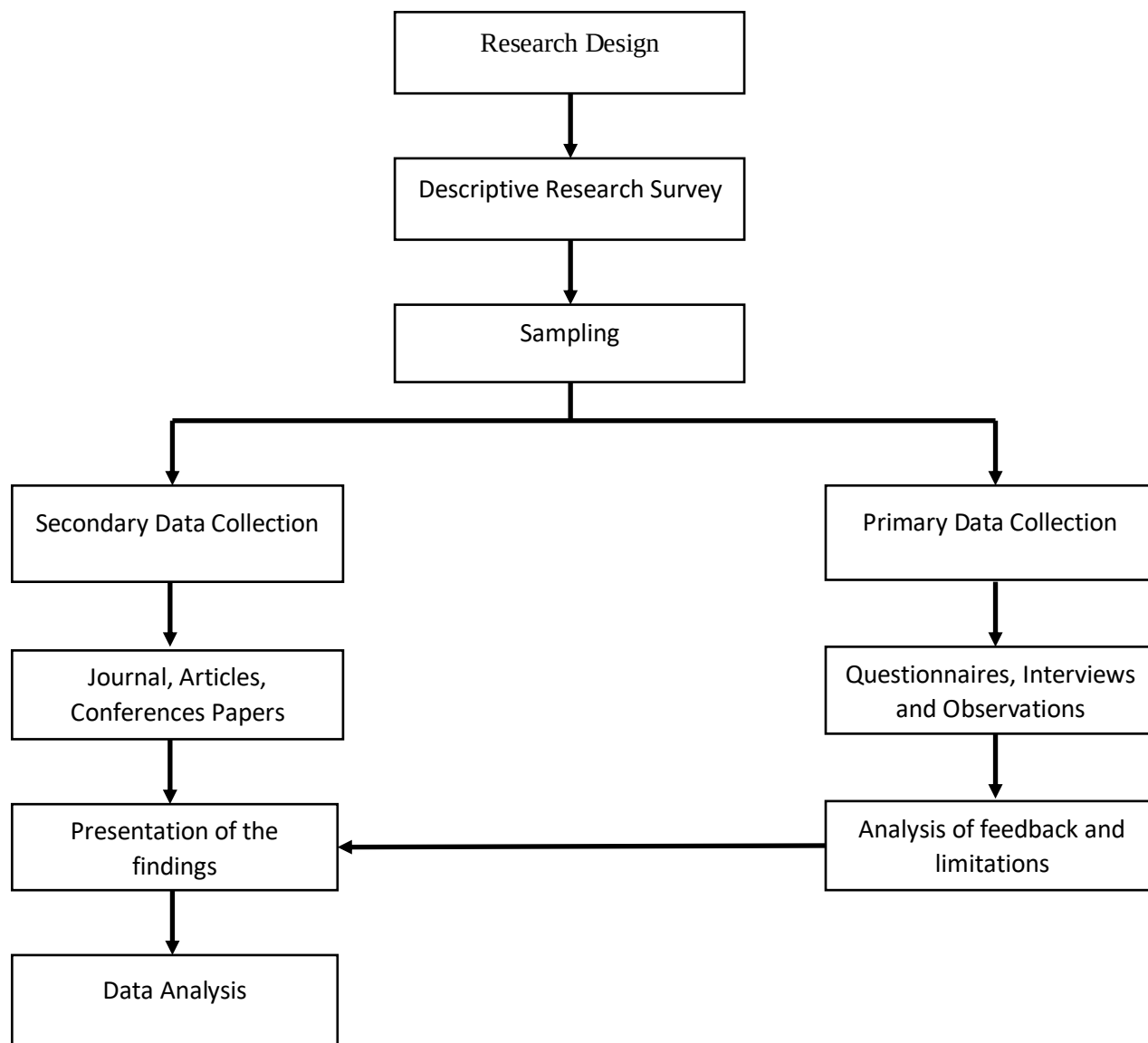


Figure 3-1: Research Methodology

3.4.2 Population and Sample

According to (Mann & Lacke, 2010) “The population of the study is all element involved in the study whose characteristics are being studied”. The population of this study is all cleaning stuff, outpatients, visitors, and employees whose number varies everyday hence the number of elements in a population cannot be determined, therefore the researcher uses the sample to generalize the findings of the research. A sample is the portion of population selected for study.

3.4.3 Unit of Inquiry

The element of inquiry is the Queen II Hospital in the Maseru area which are now under the Lesotho Millennium Development Agency. Participants are chosen from the cleaning staff, employees, visitors and outpatient ts all from the Queen II Hospital.

3.4.4 Purpose of Inquiry

The Research design was a descriptive study. The researcher will take in descriptive survey design type. The health care center survey involved investigative the overall cleaning of waste, from cleaning, collecting, moving, and throwing away the trash. The researcher focused on issues related to poor managing, controlling and supervision of waste faced by the employees, patients, visitors and the cleaning staff due to maintaining a hygienic and clean conditions on the environment.

3.4.5 Sampling Method

Stratified random sampling and random sampling method were used to draw a sample from the population to generalize the answers and make available satisfactory information to the study. Random sampling (Mann & Lacke, 2010) “is where a sample drawn in such a way that each element of the population has some chance of being included in the sample”.

In a simple random sampling (Mann & Lacke, 2010) “all samples of the same size selected from a population have the same chance of being selected”. “The advantage of stratified random sampling in a case like this is clear: it ensures that the resulting sample will be distributed in the same way as the population in terms of the stratifying criterion” adds (Bryman, 2012).

According to (Bryman, 2012) “First, you can conduct stratified sampling sensibly only when it is relatively easy to identify and allocate units to strata. If it is not possible or it would be very difficult to do so, stratified sampling will not be feasible. Second, you can use more than one stratifying criterion”. “Stratified sampling is really feasible only when the relevant information is available.

In other words, when data are available that allow the ready identification of members of the population in terms of the stratifying criterion (or criteria), it is sensible to employ this sampling method” (Bryman, 2012).

Queen II Hospital has a total of 25 employees including the part-timers, maximum of only 50 Outpatients attendant every day and records showed that at most 20 visitors come in daily, 15 cleaning staff. The admitted patients (In-Patients) were excluded as part of the population because the researcher considered them to be unfit for answering for being disturbed. Therefore researcher’s population size is approximately 110. The table below shows the categories of the people.

The sample needed to be large, so the sample size was determined by using a mathematic function mentioned below.

$$n = \frac{N}{1 + N(\alpha)^2}$$

“ where ***n*** is the sample size,

N is the population size.

α is the margin of error expected” (Bryman, 2012).

Consequently the result for substituting the formulation was:

$$n = \frac{110}{1+110(0.05)^2} = 86.274509$$

Substituting the variables, the function gives 86.274509, therefore the sample size was 86 for the entire population. “It is important to appreciate that the probability sampling cannot eliminate sampling error. The confidence level of this sample was 95% with expected errors 0.05%. Even with a well-crafted probability sample, a degree of sampling error is likely to creep in. However, the probability sampling allows the researcher to employ tests of statistical significance that permit

inferences to be made about the sample from which the sample was selected” mentioned (Bryman, 2012).

The sizes of each groups were sampled using the same mathematical sample to get the required sample for each group. The researcher used the random sampling on each strata

Table 1: Categories of participants in the study

Groups	Description
Cleaning Stuff	These are individuals that provide services of cleaning the premises of the health center and making sure the small bins are emptied and they also throw trash away in to the trash bins.
Employees	These are individuals who work at the place and use the dustbins provided to throw their trash everyday
Outpatients	These are individuals who come for services daily at the health care center and use the dustbins provided to throw their trash everyday
Visitors	These are individuals who come to visit the patients daily at the health care center and use the dustbins provided to throw their trash everyday

3.4.6 Data Collection Methods and Tools

“The collection of data is the heart of any research design, irrespective of the field of study. Any research begins with certain questions, which need to be answered. Data collection is the process of gathering the desirable information carefully, with least possible distortion, so that the analysis may provide answers that are credible and stand to logic” (Parveen & Nayeem, 2017).

Several instruments were used to collect the primary data. These instruments included, questionnaires, semi-structured face-to-face interviews and participant observation data collection method. The secondary data included the data from literature review. These methods are intended to find in-depth understandings to opinions and observations of the participants essential to the researched phenomena to assist the researchers.

Questionnaire

A method used by the researcher here is the questionnaires. “A questionnaires is a written list of question, the answers to which are recorded by respondents. In a questionnaires respondents read the questions, interpret what is expected and write down the answers”. To collect the required data, the mentioned participants from the strata were issued self-administered questionnaires. The questions included both the closed-ended and open-ended questions.

Questionnaires were structured to be simple, clear and understandable for the respondents, hence they were free to answer at their own convenience. Self-administered questionnaires were written in both Sesotho and English so as to be able to accommodate everyone who does not understand Sesotho or English and they were manually circulated to the participants. Each question on the questionnaires addressed the objectives of the study. Questionnaires will be provide as appendix.

Interview (structured or loosely structured)

An interview is another important collection method that the researcher used for gathering information from that the research participants. According to (Kumar, 2011) “any person-to-person interaction, either face-to-face or otherwise, between two or more individuals with a specific purpose in mind is called an interview”. Structured interview was another source of primary data collected. Interviews were conducted with the employees and cleaning staff. Face-to-face interview was the researcher preferred method, with these technique the researcher was able to analyze the non-verbal communication and reactions, including facial expressions and postures.

According to (Kumar, 2011) “in a structured interview the researcher ask predetermined questions, using the same wording and other of questions as specified in the interview schedule. one of the main advantages of structured interviews is that it provides uniform information which assures the comparability of data. Structured interviews requires fewer interviewing skills than does unstructured interviewing”. The interviews were structured, these structured interviews were conducted with six employees and 2 cleaning staff members.

Observation

Another method the researcher used to gather the data was an observation method. “Observation is a purposeful, systematic and selective way of watching and listening to an interaction or phenomenon as it takes place” (Kumar, 2011). Participant observation was done by the researcher by making several weekly visits to the health center. (Kumar, 2011) Mentions “participant observation is when you as the researcher, participate in the activities of the group being observed in the same manner as its members, with or without their knowing that they are being observed”.

The observation made was then compared to the answers provided through questionnaires. The observation made was of cleaning that of overflowing bins after two day on the third day the waste is already scattered all over the place. The researcher observation is inconclusive because sometimes the bins fill up within a day or two, sometime it takes three to four days to fill. Collection truck making collection while the bins are still below and close to half full and also when the bins fill up within a short period of time, then collections are not made.

“The main advantage of participation observation is that as you spend sufficient time with the group or in the situation, you gain much deeper, richer and more accurate information, but the main disadvantage is that, if you are not careful, you can introduce your own bias” stated (Kumar, 2011).

Table 2: A weekly observation based on the daily status of the bin

Days	People's behavior	Status of the environment	Cleaning staff conduct with waste when the bin is Full	Status of the Wheel Bin	Waste Management Issues	Wheel bin collections
Monday	A few people do not use the bins provided to throw their trash	Plastic bags and trash outside of the wheel bins	Throw plastic bags outside of the wheel bin	Full and over flowing	Trash Scattered Bad Odor, Flies	Done
Tuesday	A few people do not use the bins provided to throw their trash	Environment clean	Throw plastic bags outside of the wheel bin	Wheel bins emptied and half full	No Issues	Not done
Wednesday	A few people do not use the bins provided to throw their trash	Environment partly clean	Throw plastic bags outside of the wheel bin	Wheel bins full	Dirty Environment, Scattered waste, Bad Odor, Flies	Not done
Thursday	A few people do not use the bins provided to throw their trash	Environment clean	Environment clean	Wheel bins empty	No issues	Done
Friday	A few people do not use the bins provided to throw their trash	Environment clean	Environment clean	Wheel bins half full	No issues	Not done
Saturday	A few people do not use the	Environment partly clean	Throw plastic bags outside	Wheel bins full	Dirty Environment,	Not done

	bins provided to throw their trash		of the wheel bin		Scattered waste	
Sunday	A few people do not use the bins provided to throw their trash	Environment partly clean	Throw plastic bags outside of the wheel bin	Wheel bins full and overflowing	Dirty Environment, Scattered waste, Bad Odor, Flies	Not done

Secondary Data

Data is collected from previews literature reviews, on journals, article, research papers, conferences, magazines, government reports and data collected from LMDA “reports’ submitted by different private companies.

3.4.7 Data Analysis

Upon completion of questionnaires by the participants, the questionnaires were all collected by the researcher. The descriptive and statistical information was organized and studied and stored in a manner that is possible to analyze the data. Microsoft excel was used to captured and analyze the data into charts and graphs.

3.4.8 Ethical Considerations

In a research study, ethical issues are of utmost concern. Participant require trust from the researchers, they need to know that the information they provide will be protected at all cost. To avoid negativity the researcher is obliged to adhere to following agreements: The participants were treated with utmost respect, the value of privacy of all respondents partaking in the research was warranted. Participation was made clear to the participants that it is purely voluntary. Participants were presented with concerned forms data collected from such questionnaires was used and

analyzed legitimately because all questionnaires that were used were only the ones that the participants contracted their concerned forms.

All participants were made aware that is not a must to commit to the questionnaires and that at any point in time that they are not at ease in answering questions, they can leave them blank and that they have the right to stop partaking in the interview whenever they like. Confidentiality of interviews and questionnaires was maintained; they were also given an option to hide their identities or that their identities will not be revealed.

The researcher was cautious to avoided non-judgmental gestures headed for the participant. The researcher's best approach and responsibility was to make and allow willing participants were made and allowed to choose a more conducive place for the interviews so that they feel at ease enough and as a result communicate freely and openly.

3.4.9 Research Limitations

The researcher faced difficulties in getting all the required sample to participate, some participants showed lack of interest, which meant visiting the Queen II Hospital several more times than anticipated to get the required sample, while others did not bring back the questionnaires. Some interview were cancelled which meant scheduling of other interviews that meant another delay.

Chapter 4: Design and Implementation

4.1 Introduction

This chapter discusses the general design of the proposed solution, the block diagram manifesting the components and the way they are structured. The circuit diagram depicting the actual implementation of the hardware components of the system and the two part needed for the two programs. The overall cycle of monitoring the status of the bin.

4.2 Block Diagram

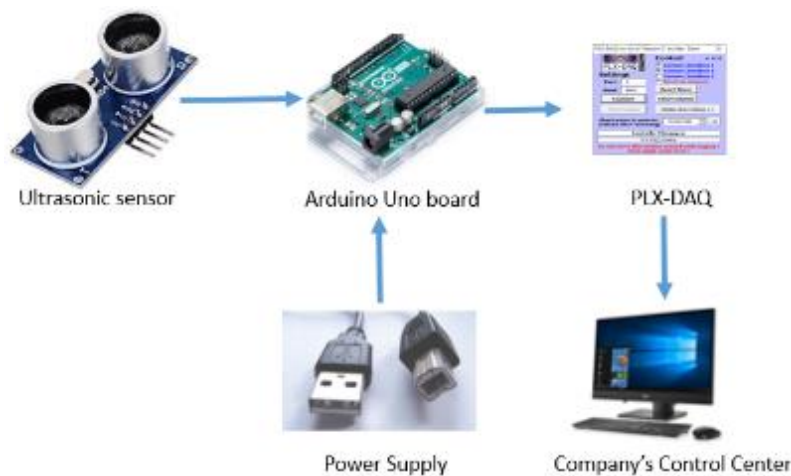


Figure 4-1: Block Diagram (Author)

The block diagram illustrates the basic set-up of the system. The large waste bins outside of the health center are interfaced with the ultrasonic sensor to measure how far the distance of the trash inside the bin is to the trash lid, where the sensor is located. The status of the bin from the ultrasonic sensor is sent to the Arduino, and on the set time the results in the Arduino are communicated with excel. The information is displayed and recorded, stored and graphed for future analysis.

The authorized personnel in the control center uses the PLX DAQ to monitor the status of the bin and makes the decisions of which bins are to be collected as they have reached the required fill level. The collection are only made when the bins are full. Once the bin are cleaned, the graphs will return to an empty level as the ultrasonic sensor will not detect any trash inside the bin and the same information will automatically be reflected of recorded on the excel.

4.3 Hardware and Software requirements for this project:

- Arduino Uno
- USB A-to-B Cable
- Arduino Breadboard
- Jumper Wires
- Ultrasonic Sensor (HC-SR04)
- Power Supply

Hardware Requirements:

Arduino Uno: Arduino Uno is the most common because of its features and simplicity. According to (Makerspace, n.d.) “Arduino is an open source programmable circuit board that can be integrated into a wide variety of makerspace projects both simple and complex. This board contains a microcontroller which is able to be programmed to sense and control objects in the physical world”.

The Arduino responds and controls components you attach to it. Outputs such as LEDs, motors and displays” mentions (Geddes, 2016) and (Makerspace, n.d.). “There are 14 digital input/output pins (pins 0–13). Each can be set to either input or output” adds (Geddes, 2016).

To program the Arduino (Geddes, 2016) stated that the batteries, the USB, or an external power are requirements for sources of power in order to program and use the Arduino. The USB cable is used when connecting the Arduino directly to the computer and then it can program the Arduino, and the Arduino can be disconnected from the computer and it will work autonomously by means of batteries or by way of a power supply.

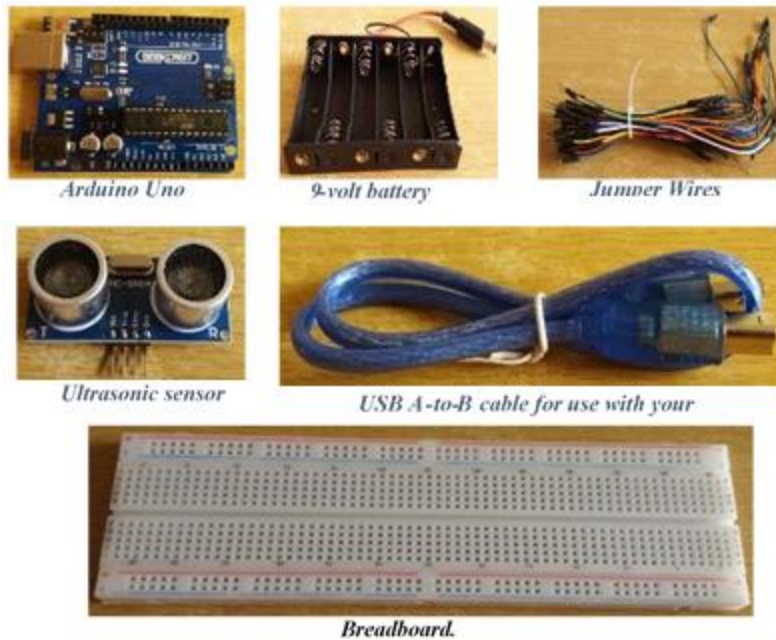


Figure 4-2: Hardware Requirements for the Project.

Arduino Power Supply: “The Arduino Uno needs a power source in order for it to operate and can be powered in a variety of ways. You can do what most people do and connect the board directly to your computer via a USB cable. If you want your project to be mobile, consider using a 9V battery pack to give it juice. The last method would be to use a 9V AC power supply” (Makerspace, n.d.). The following are the USB and external power source.

USB Cable: “Allows connection of Arduino Uno to the computer for programming. It also provides power to the Arduino” (Fitzgerald, et al., 2012) and (Geddes, 2016) agrees “The Arduino Uno board is powered from your computer’s USB port when you connect it to your PC to upload a program”.

9-volt battery pack: “When the Arduino is not linked to your PC, you can run it independently by connecting a 9-volt AC adapter or 9-volt battery pack with a 2.1 mm jack, with the center pin connected to the positive wire. Simply insert the jack into the power socket of the Arduino”.

Arduino Breadboard: “is a board on which electronic circuits are build. It’s like a patch panel, with rows of holes that allow wires and components to be easily connected together” (Fitzgerald, et al., 2012). According to (Makerspace, n.d.) “The solderless breadboard allows you to prototype

your Arduino project without having to permanently solder the circuit together. Using a breadboard allows you to create temporary prototypes and experiment with different circuit designs. Inside the holes (tie points) of the plastic housing, are metal clips which are connected to each other by strips of conductive material”.

Jumper Wires: The ultrasonic sensor and the Arduino Uno and the solderless breadboard needs to connect together to be able to interact with each other and to accomplish the connection (Geddes, 2016) states “jumper wires make connections on the breadboard. Jumper wires are solid-core wires with a molded plastic holder on each end that makes it easier to insert and remove the wires” (Geddes, 2016). “The breadboard is not powered on its own and needs power brought to it from the Arduino board using jumper wires. These wires are also used to form the circuit by connecting resistors, switches and other components together” adds (Makerspace, n.d.)

Ultrasonic Sensors (HC-SR04): Used to detect the closeness of waste fill in the bin. “HC-SR04 Ultrasonic (US) sensor is a 4 pin module, whose pin names are Vcc, Trigger, Echo and Ground respectively” (COMPONENTS 101, 2017).

“The contacts 5V and GND are meant for the power supply. Through the trigger pin the sensor gets a short signal (5V) from the microcontroller board to create a sound wave. As soon as the sound wave hits a wall or other objects, it will be reflected and comes back to the ultrasonic sensor. When the sensor detects this returned sound wave, the sensor will send a signal to the Arduino microcontroller through the echo pin. The Arduino-board measures the time between the transmission and the return of the sound wave, and converts this time into a distance” (Makerspace, n.d.).

User’ personal computer: the control unit receives information to the computer through PLX DAQ, opening the excel and connecting allows the waste level data in the bin to be displayed and once the data is there it can be graphed using different graphs and charts. This is actually where the authorized waste collectors can monitor when the bin has reached the required level of pickup in the control center.

Software Requirements:

Arduino IDE: The Arduino is programmed with instructions this simply means that the Arduino need written programs for it to receive information. “The Arduino software is called the Arduino integrated development environment (IDE), The IDE is a simple interface that runs on a computer running Windows, OS X, or Linux. You use the IDE to create a sketch (an Arduino program) that you then upload to the Arduino board using a PC and USB cable” (Geddes, 2016). According to (Aruna & Priya, 2018) “Arduino (IDE) is a programming platform for Arduino microcontrollers”.

Writing Sketches in the Arduino

“The IDE is divided into a toolbar at the top, with buttons for the most commonly used functions; the code or sketch window in the center, where you’ll write or view your programs; and the Serial Output window at the bottom. The Serial Output window displays communication messages between your PC and the Arduino, and will also list any errors if your sketch doesn’t compile properly” (Geddes, 2016).



Figure 4-3: The ide interface.

PLX DAQ:

According to (Nichols, 2017) “PLX-DAX is a Parallax Data Acquisition Tool free add-ins for Microsoft Excel”. “PLX-DAX is really a macro that runs in Microsoft Excel. It is free and can be downloaded from Parallax, Inc. It reads data coming on the serial port, it’s really independent of a specific microcontroller as long as the correct command words are sent over the USB bus” states (Bogatin, 2015).

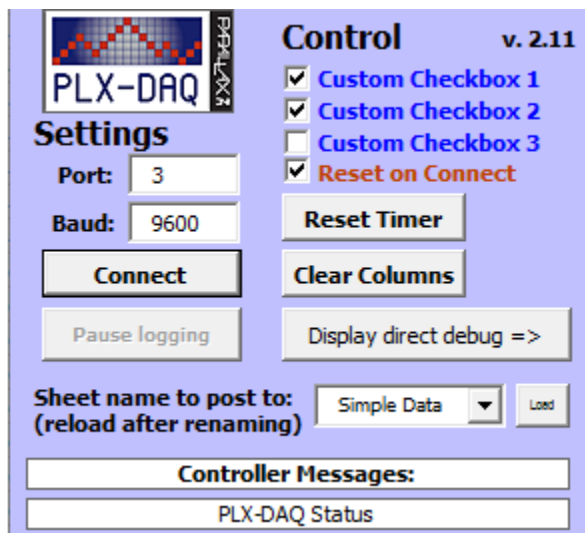


Figure 4-4: Parallax Data Acquisition Tool

4.4 Circuit Connections

The design and implementation of the Ultrasonic Sensor (HC-SR04) and an Arduino Uno board displays calculated percentage of an obstacle on the serial monitor and on an excel.

The Arduino is plugged to the USB A-to-B Cable power supply and connected to the laptop so that it can be programmed. The Ultrasonic Sensor has four pins where the pins are connected to the pins on the Arduino. “The Arduino program receives this information and calculates the distance between the sensor and object” (Autodesk, inc., 2019).

There are four (4) to the ultrasonic sensor are GND pin, echo pin, which the image signal is read from. The trig pin that is meant to transfer the ultrasonic sound and then lastly the Vcc pin that provide 5V to power the ultrasonic sensor and there are 28 pins in the Arduino Uno among which the Vcc, GND pin1-9. To connect with the Ultrasonic sensor

The Ultrasonic sensor is plugged onto the solderless breadboard, the jumpers were used to connect “the Power the Sensor using a regulated +5V through the Vcc ad Ground pins of the sensor. The current consumed by the sensor is less than 15mA and hence can be directly powered by the on board 5V pins. The Trigger and the Echo pins are both I/O pins and hence they can be connected to I/O pins of the microcontroller” (COMPONENTS 101, 2017).

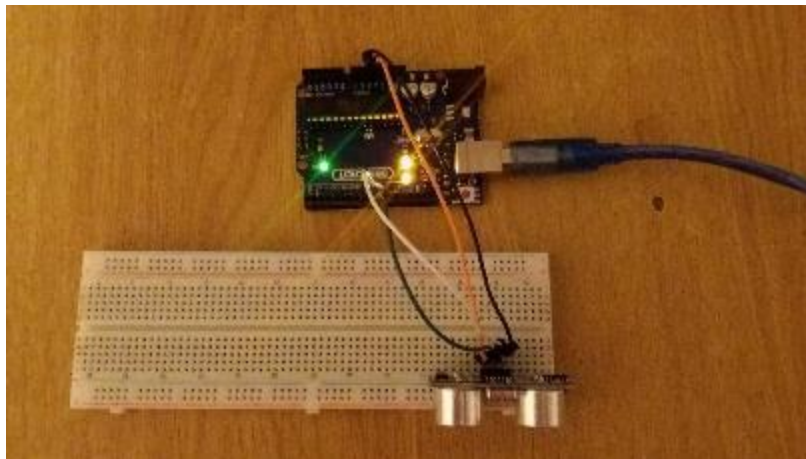


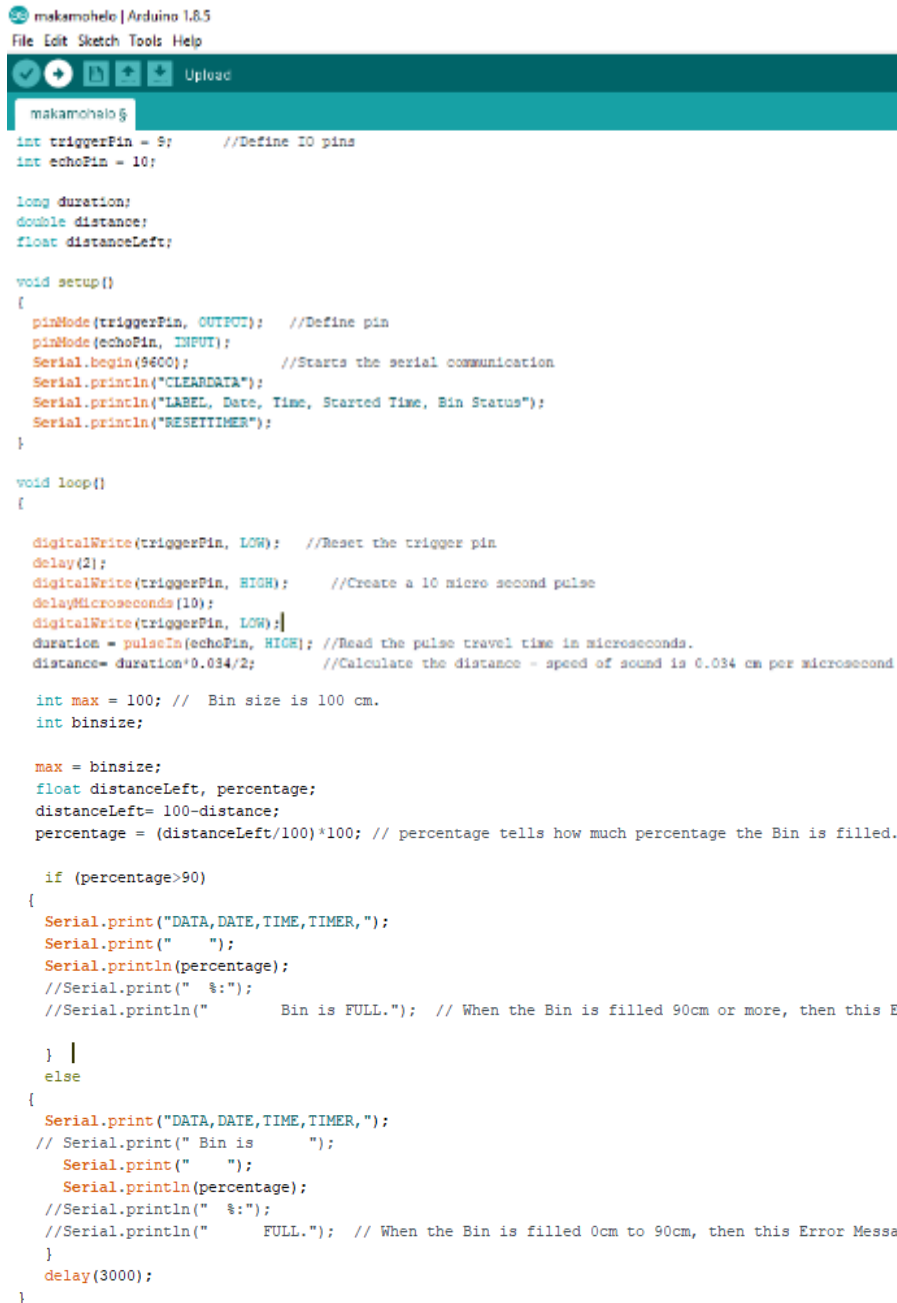
Figure 4-5: Implementation of Trash monitoring

4.5 Arduino to Excel Communication

The project aims to monitor and collect status of the bin in real time. Graph the data and use it for future reference.

4.5.1 The Arduino IDE code

Arduino to Excel Communication programs are separated into two parts. First the Arduino is programmed with the Arduino IDE. The Ultrasonic sensor calculates the distance of trash approaching using the ultrasonic sound waves and then collects the data as the bin gets filled with trash. The data is received in real-time and can be monitored on the serial monitor and graphed using the serial plotter.



```

makamohelo | Arduino 1.8.5
File Edit Sketch Tools Help

makamohelo §
int triggerPin = 9;    //Define IO pins
int echoPin = 10;

long duration;
double distance;
float distanceLeft;

void setup()
{
  pinMode(triggerPin, OUTPUT); //Define pin
  pinMode(echoPin, INPUT);
  Serial.begin(9600); //Starts the serial communication
  Serial.println("CLEARDATA");
  Serial.println("LABEL, Date, Time, Started Time, Bin Status");
  Serial.println("RESETTIMER");
}

void loop()
{
  digitalWrite(triggerPin, LOW); //Reset the trigger pin
  delay(2);
  digitalWrite(triggerPin, HIGH); //Create a 10 micro second pulse
  delayMicroseconds(10);
  digitalWrite(triggerPin, LOW);
  duration = pulseIn(echoPin, HIGH); //Read the pulse travel time in microseconds.
  distance= duration*0.034/2; //Calculate the distance - speed of sound is 0.034 cm per microsecond

  int max = 100; // Bin size is 100 cm.
  int binsize;

  max = binsize;
  float distanceLeft, percentage;
  distanceLeft= 100-distance;
  percentage = (distanceLeft/100)*100; // percentage tells how much percentage the Bin is filled.

  if (percentage>90)
  {
    Serial.print("DATA,DATE,TIME,TIMER,");
    Serial.print(" ");
    Serial.println(percentge);
    //Serial.print(" %:");
    //Serial.println(" Bin is FULL."); // When the Bin is filled 90cm or more, then this Error Message will Displayed.
  }
  else
  {
    Serial.print("DATA,DATE,TIME,TIMER,");
    // Serial.print(" Bin is ");
    Serial.print(" ");
    Serial.println(percentge);
    //Serial.println(" %:");
    //Serial.println(" FULL."); // When the Bin is filled 0cm to 90cm, then this Error Message will Displayed.
  }
  delay(3000);
}

```

Figure 4-6: Arduino IDE Code

4.5.2 PLX-DAQ v 2.11 Connection

The second part of the code is the PLX-DAQ v 2.11 latest version. The Excel spreadsheet code is modified according to the needs of the researcher's project. Once the circuitry system is ready the code is run and compiled on the Arduino IDE, tested on the serial monitor and serial plotter. Then the PLX-DAQ excel spreadsheet shortcut is opened for monitoring the data. The Excel requires the port 3 and bound 9600 that corresponds to the Arduino Uno code. In these case the port is 3 from COM3 and baud is 9600. Then the connect button is clicked, automatically the data is received, together with the current date and time on the device used. According to (Parallax Inc , 2019) "PLX-DAQ provides easy spreadsheet analysis of data collected in the field, laboratory analysis of sensors and real-time equipment monitoring". The data can then be graphed for record keeping.

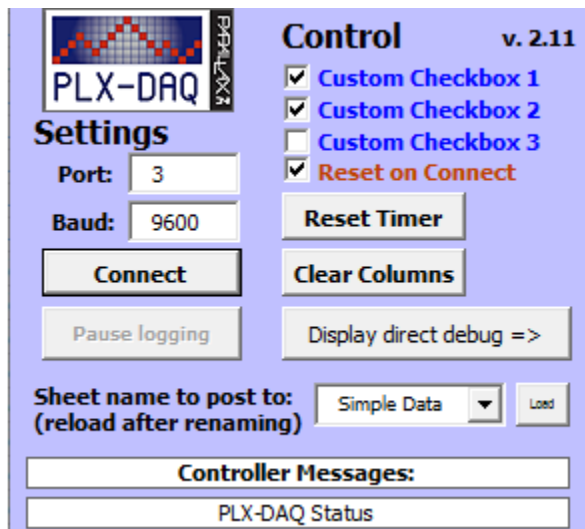


Figure 4-7: PLX-DAQ Connect Interface

4.5.3 Cycle of Arduino to Excel Communication

The cycle shows the Arduino receiving the data from Ultrasonic sensor then sending the data via Excel. The ultrasonic sensor collecting the data and the processing done in the Arduino. The user monitors the data in the spreadsheet analyze the data and graph the data.



Figure 4-8: Arduino to Excel Communication Life Cycle

4.6 Ultrasonic Sensor Distance Measurement

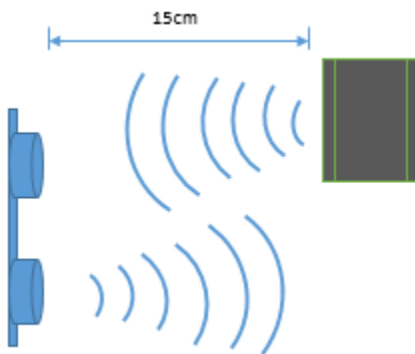


Figure 4-9: Ultrasound travelling through the air and hitting an object

Figure 4-9 above shows when “the ultrasonic sensor uses sonar to determine the distance to an object. The transmitter (trig pin) sends a signal: a high-frequency sound. When the signal finds an object, it is reflected and the transmitter (echo pin) receives it” (Santos, 2019).

“The HC-SR04 ultrasonic sensor uses sonar to determine distance to an object like bats do. It offers excellent non-contact range detection with high accuracy and stable readings in an easy-to-use

package. It comes complete with ultrasonic transmitter and receiver modules” (Santos, 2019). “The time between the transmission and reception of the signal allows us to calculate the distance to an object. This is possible because we know the sound’s velocity in the air”, further explained (Santos, 2019).

Now, if an object is 15 cm away, the distance is calculated this way:

(Weebly, 2019) Stated “**The speed of sound in microseconds**

$$v = 340m/s \quad \text{Or}$$

$$v = 0.034 \text{ cm}/\mu s$$

Time = distance/speed

$$t = \frac{s}{v} = \frac{15}{0.034} = 441\mu s$$

Distance in cm

$$s = t * \frac{0.034}{2}$$

“Pulse length/ (Speed of sound x 2) = Distance in cm as the ping travels to and fro, we need to divide the distance by 2” stated (Weebly, 2019).

4.7 Flow chart to Arduino to Excel Communication

The flow chart shows the data collected on the excel spread sheet, first the shortcut to excel spreadsheet is opened in the PLX-DAQ folder. The connection is made so that excel collects the data in real time. The data is continually monitored through the Excel. If the status of the bin reaches above 90 percent, the collections are made. If the level is below the 90 percent the control room keeps monitoring the status of the bin to make sure the bins do no overflow. Then the process is repeated all over again.

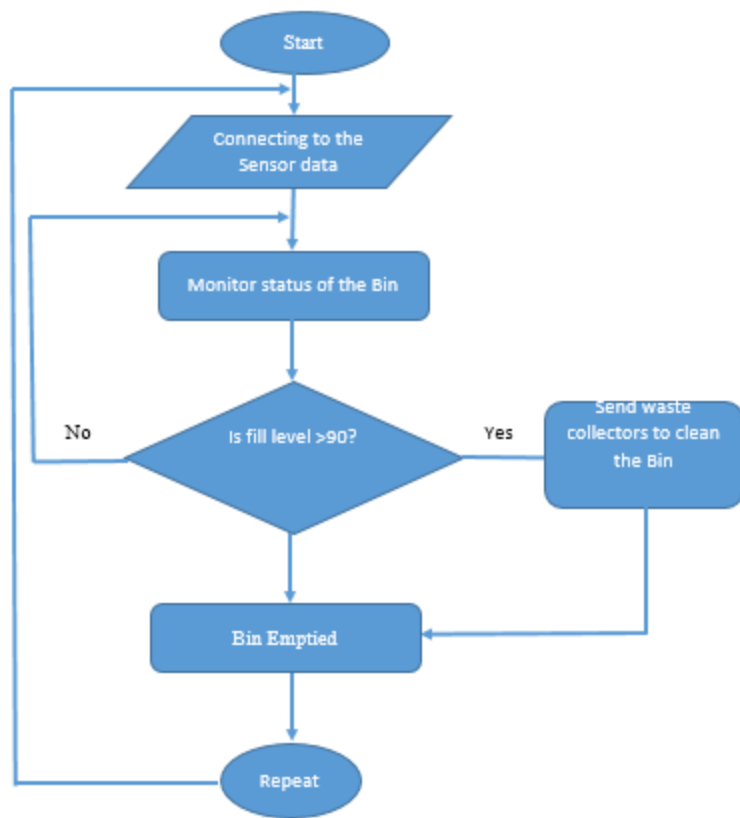


Figure 4-10: Arduino to Excel Communication Flow Chart

Chapter 5: Data Analysis, Presentation and Interpretation

5.1 Introduction

This chapter presents an outlines and illustrations of the researcher's analysis of findings of the waste management system that currently exists in the Queen II Hospital. The main objective in to this chapter is to bring interpretations to observations and responses to questionnaire and find the best solutions to waste management to keep the environment clean and maintain hygienic conditions.

The survey findings and results of the research study are analyzed and interpreted in this chapter. The findings comprise of respondents demographic the influence to the study, how the participants are affected by waste and or waste management, the shape and state of the current collection system, and the look and feel of the environment with the existing system. The results of observations, opinions and view on current issues and problems with waste managements and the impact of health issues on the lives of people and animals due to the issues raised by participant issues.

The results of the data are based on the demographics of the respondents, and the priority of the most relevant and important questions of the survey are analyzed and presented using tables, charts and graphs: bar and pie charts. This mainly assists in developing and understanding the relationship that exists between all the entities involved.

5.2 Statistics

Out of a sample of 86 participants an overall of 72 completed the questionnaires. The data analysis of the tables was made with the SPSS while excel was used for the illustration of the graphs. The statistics based on the analysis of the priority questions on the questionnaire the respondents took part in. The data analysis feedback is on the 72 respondents that filled and submitted the questionnaires from the sample of 86 in total. **Table 3** below is from the SPSS.

Table 3: Statistics of the respondents

Statistics

		Age	Gender	Waste Management issues Minimized with Proper Waste Management	Frequency of Bin Overflow	Opinion Current Waste Management
N	Valid	72	72	72	72	72
	Missing	0	0	0	0	0

5.3 Demographics

The demographics of the respondents were requested to provide were the age and gender. **Table 4** is the SPSS frequency table which shows that the out of the 72 respondents, the most popular gender group were the female group totaling 50 with valid percent of (69.4%) and male group respondents totaling 22, had a valid percent of 30.6%.

Table 4: Female group is the most popular

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	22	30.6	30.6	30.6
	Female	50	69.4	69.4	100.0
	Total	72	100.0	100.0	

Table-5 shows the SPSS frequencies of the respondents by age. The common age group is 31-40 years with a valid percent of 47.2 percent, under 20 years with the cumulative percent of 15.3, respondents with 20-30 years with 20.8 valid percent, 41-50 years of age with a valid percent of 8.3 percent and lastly those who are 50 years and above had a valid percent of 8.3 percent.

Table 5: Frequencies of the respondents by Age group

Age

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Under 20	11	15.3	15.3	15.3
20-30	15	20.8	20.8	36.1
31-40	34	47.2	47.2	83.3
41-50	6	8.3	8.3	91.7
50 and above	6	8.3	8.3	100.0
Total	11	100.0	100.0	

Figure 5-1, is the excel bar chart that shows that the highest pick of females emerged from age group 31 years to 40 years which had a cumulative percentage total of 27.8% while male had the cumulative percentage total of 19.4%. Respondents below 20 years, women had the cumulative percent of 12.5% while that of male had the cumulative total of 2.8%. Female between 41 to 50 years had cumulative percent of 63.9 and males had the cumulative percent of 27.8% and females above 50 years had cumulative percentage of 69.4% and males had 30.6% cumulative percentage.

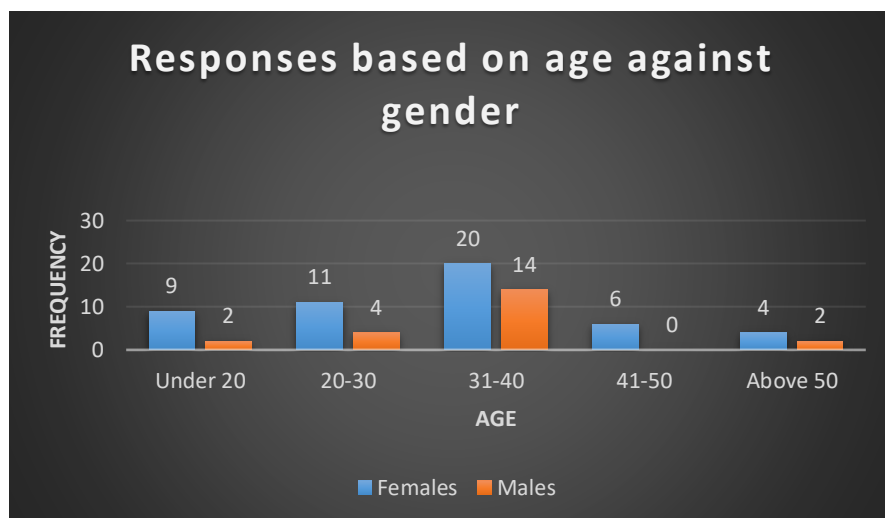


Figure 5-1: Responses based on Demographics: Age and Gender

5.4 Current Waste Management

The respondent's observations on the current traditional waste management are shows that 45% agree there is a problem with the current practice of waste collection that is being implemented, 27.8% is undecided and the remaining 26.4% disagree that there is a problem with waste collection.

Table 6: Opinion of respondents on if they believe there is a problem with waste management

Do you think there is a Problem with Waste Management

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	10	13.9	13.9	13.9
	Agree	23	31.9	31.9	45.8
	Undecided	20	27.8	27.8	73.6
	Disagree	16	22.2	22.2	95.8
	Strongly Disagree	3	4.2	4.2	100.0
	Total	11	100.0	100.0	

Table 6 shows the SPSS frequency table of how many participants believe waste management is a problem at the Queen II Hospital based on a Likert scale. 10 respondents with the highest frequency agree with a valid percent of 13.9%, 23 respondents strongly agree with a valid percent of 27.8%, 20 respondents are undecided with a valid percent of 27.8% and 16 respondents disagree with a valid percent of 22.2%. With this results the researcher is sure that there is a problem with the current waste management

Figure 5-2 and **Figure 5-3** is the excel bar graph and pie chart respectively, that shows how many participants separated into females and males think waste management is a problem at the Queen II Hospital based on a Likert scale. **Figure 5-2** shows the female group is still the most popular in the two groups. 23 participants agree and are the ones with the highest female frequency of 16, males with 7. 8 females and 2 males strongly agree, 15 females and 5 males are undecided and 9 females and 7 males disagree and lastly 2 females and 1 male strongly disagree.

Figure 5-3 shows the totals in each category of the Likert scale with 27.8% strongly agree, 52.8% agree, 15.3 undecided, 4.2 disagree and none of the respondents strongly disagree.

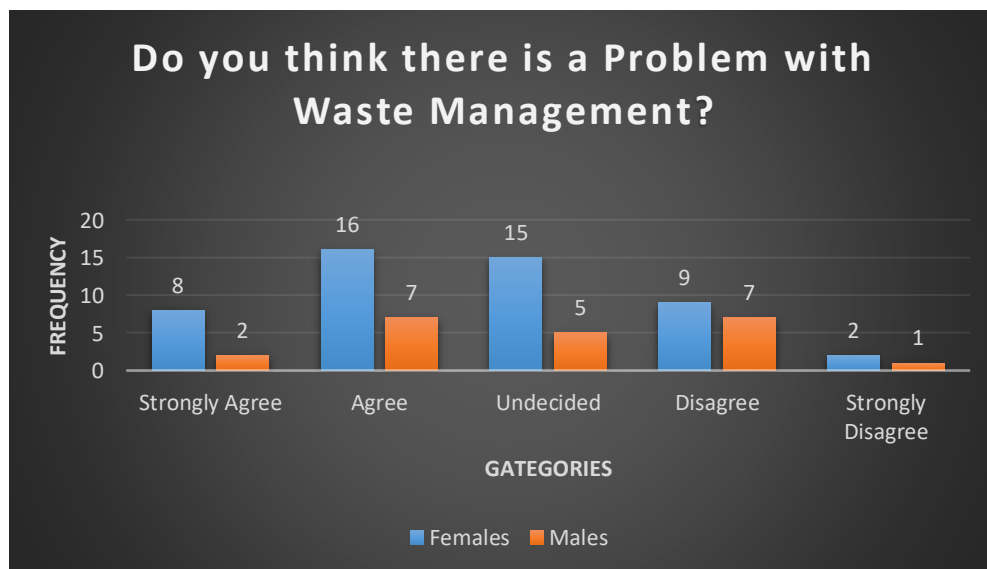


Figure 5-2: Are there problems associated with waste management at the Queen II Hospital

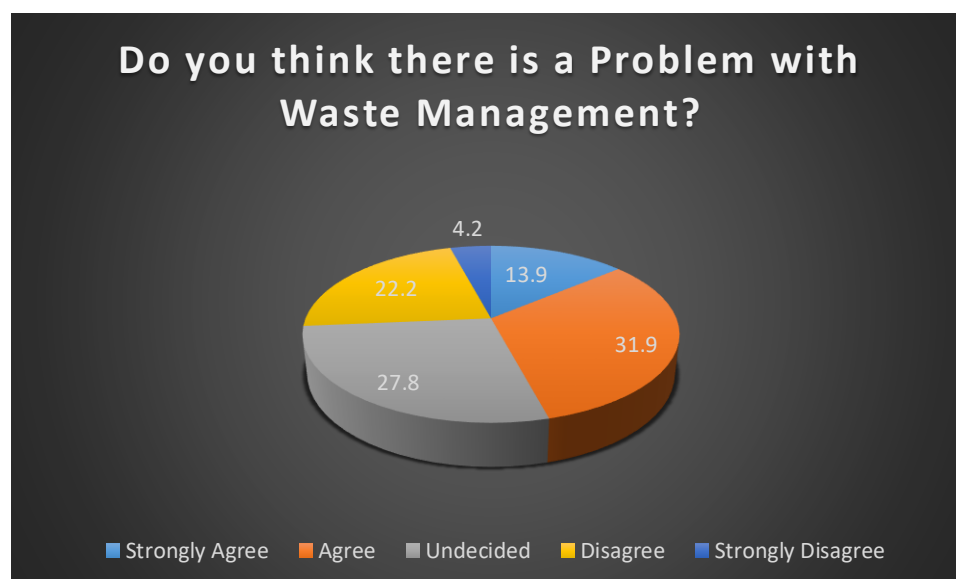


Figure 5-3: Likert scale on problems with waste management at the Queen II Hospital

5.5 Dustbins overflow

Figure 5-4 and **figure 5-5** shows the responses of all the participants on how often they notice waste overflow. The Likert scale showed that 4 participants responded very often, 9 participants responded Often, 27 occasionally, 23 participants responded rarely and 9 of them responded Never, this statistics shows that waste overflow is the major problem in waste management at the Queen II Hospital.

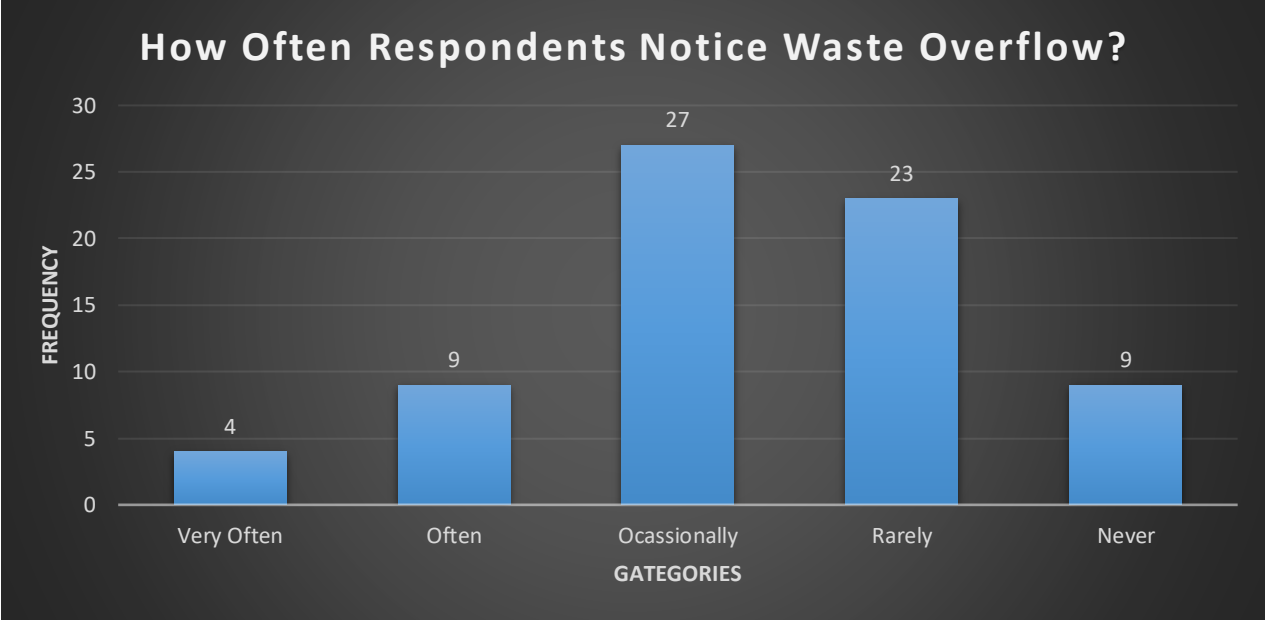


Figure 5-4: Waste Overflow

Figure 5-5 shows majority of the respondents with 37.5 % responded occasionally, 31.9 % responded rarely, 12.5 % responded very often and never respectively and 5.6 % responded often.

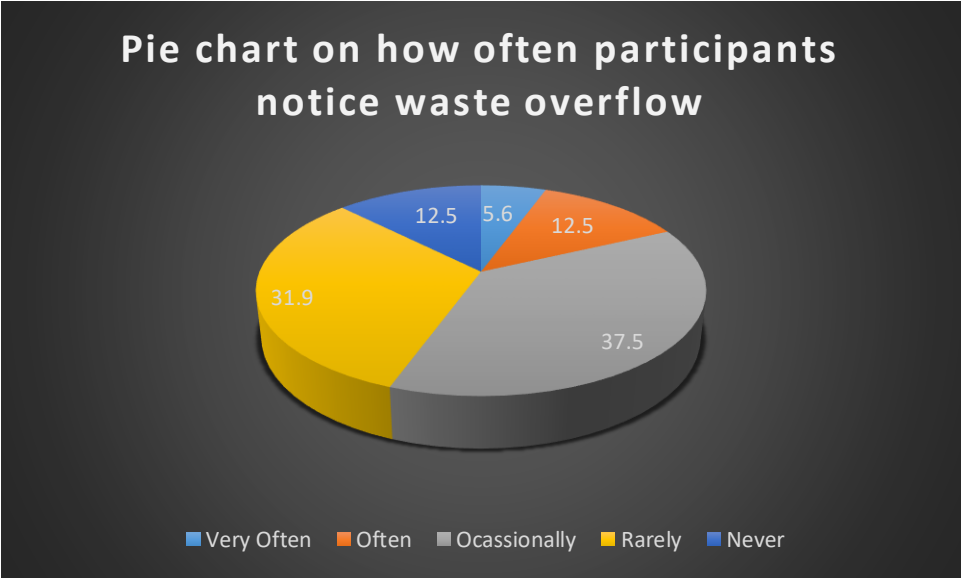


Figure 5-5: How often participants notice waste overflow

5.6 Environmental cleanliness

Figure 5-6 and **figure 5-7** shows the opinions of the respondents on the current waste management. Rarely bad had the most responses with 33 with a 45.8%, 31 respondents said rarely bad, 21 respondents with a 29.2% responded satisfactory, 6 with 8.3% responded Good and 13 with 18.1% responded Bad. This results proved that the current waste collection is not effective and most respondents agree that it is not satisfactory.

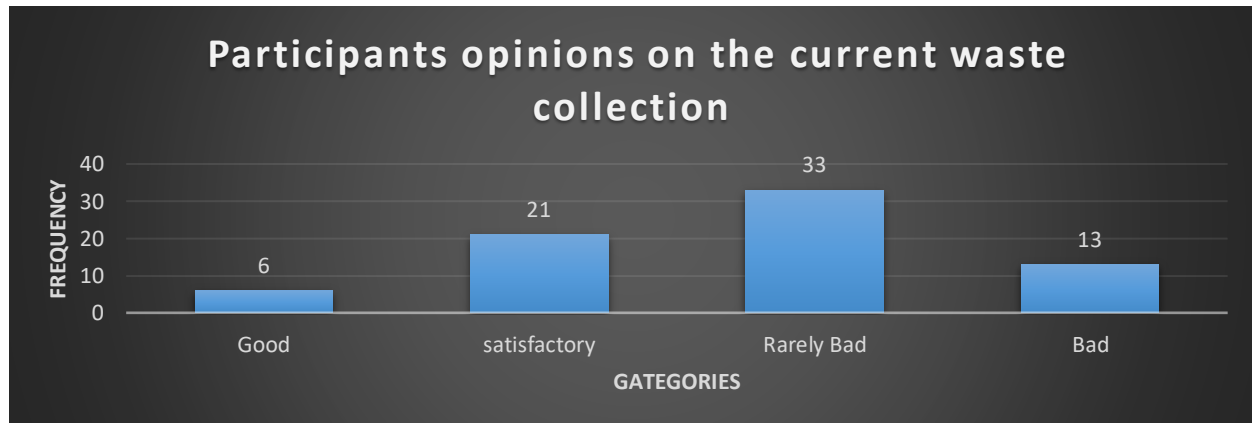


Figure 5-6: Opinions of the respondents on the current waste management

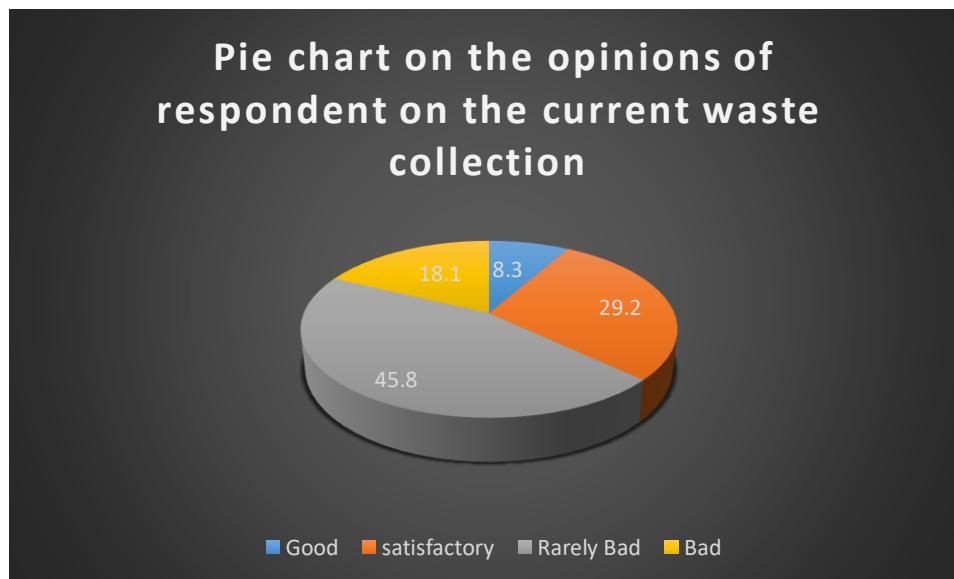


Figure 5-7: Pie chart on the opinions of respondent on the current waste collection

5.7 Monitoring Bin Status on the serial Monitor of IDE

Figure 5-8 shows seal time data collected on the serial monitor of the Arduino IDE on COM3.

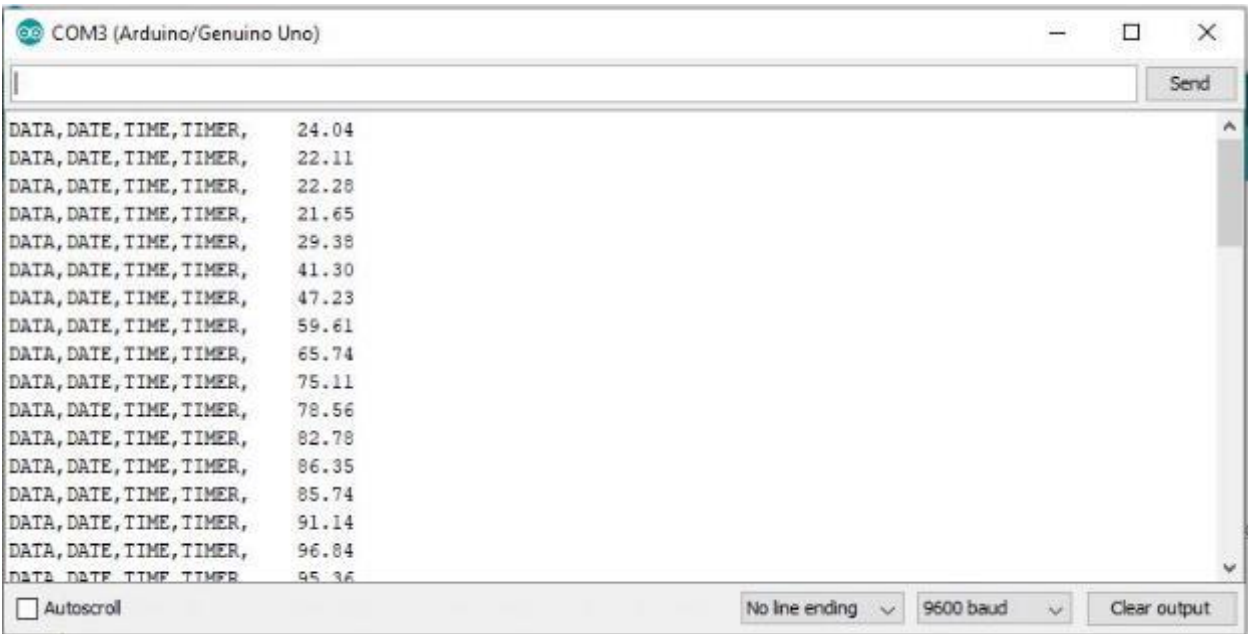


Figure 5-8: Data received in real-time on the serial Monitor of the Arduino IDE

Figure 5-9 shows the real-time data recorded on the serial plotter.

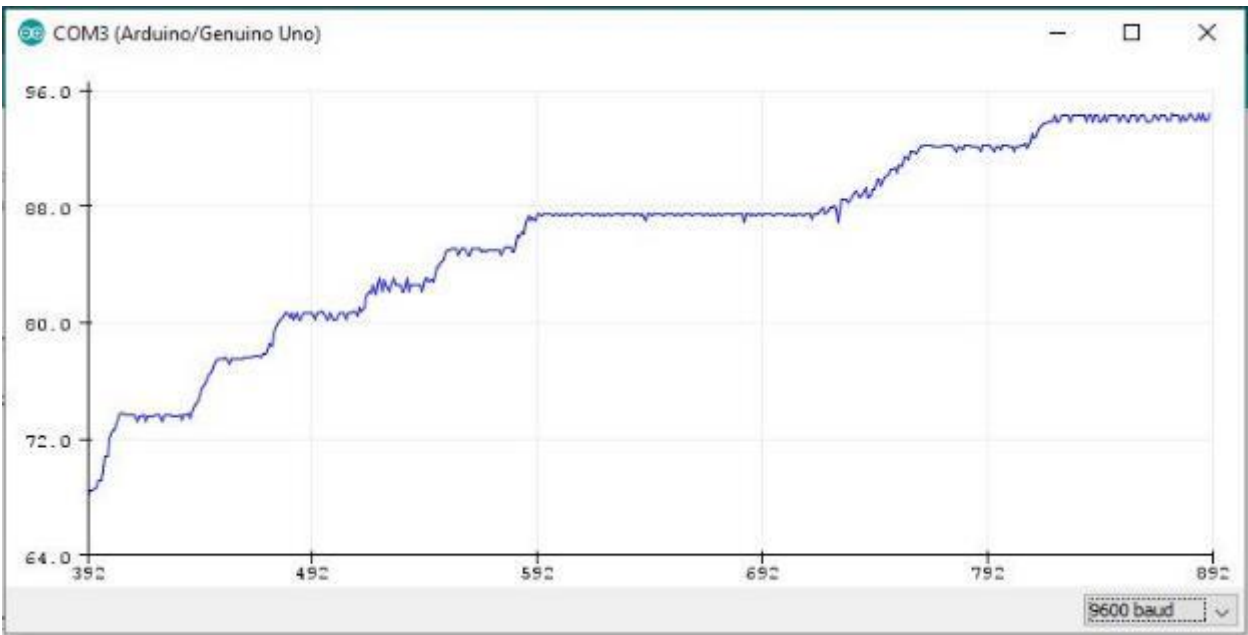


Figure 5-9: Graphing Data received in real-time on the serial Monitor of the Arduino IDE

5.8 Bin Status Monitoring on the PLX-DAQ

The PLX-DAQ version 2.11 is opened, the port is 3 since on the Arduino IDE port that is connected to COM3, bound is 9600 and connect button is clicked, and the data about the status of the bin is recorded in real-time. There are actually two parts that the program uses in order to record and plot, that is the special Microsoft Excel Spreadsheet with the PLX-DAQ v2 UI and commands plus any Arduino device that sends special commands for communication.

Figure 5-10 below shows these data recorded in real-time. The columns are the date, Time, Timer which takes the actual date and time the data is recorded on the laptop or computer that is being used, and bin status as the trash slowly approaches and the sensor records the data in percentage. When the bin is 90 percent and greater the bin status shows the bin is full, if the percentage is 90 percent and less the readings shows the trash percentage in the bin.

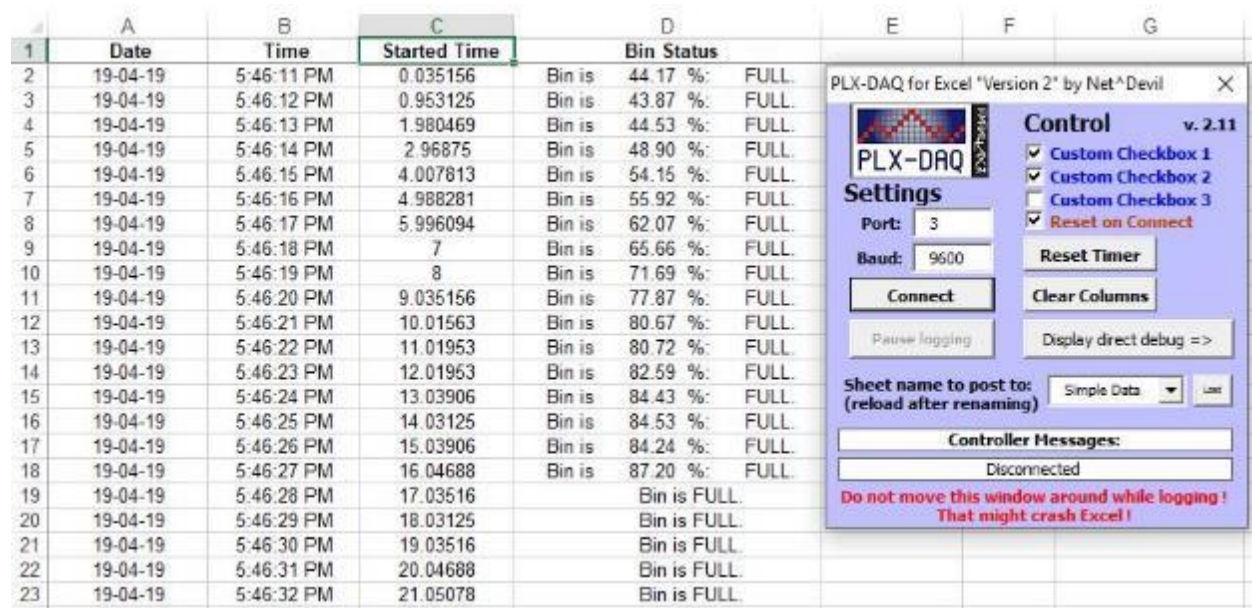


Figure 5-10:Real-time Data Monitoring on the PLX-DAQ

Figure 5-11 and **Figure 5-12** below shows bar graph data on the status of the bin. 92.2 % - 94.98% means that the bin is full then collections can be made. 72.46% - 88.01% means that the bin is about to get full.

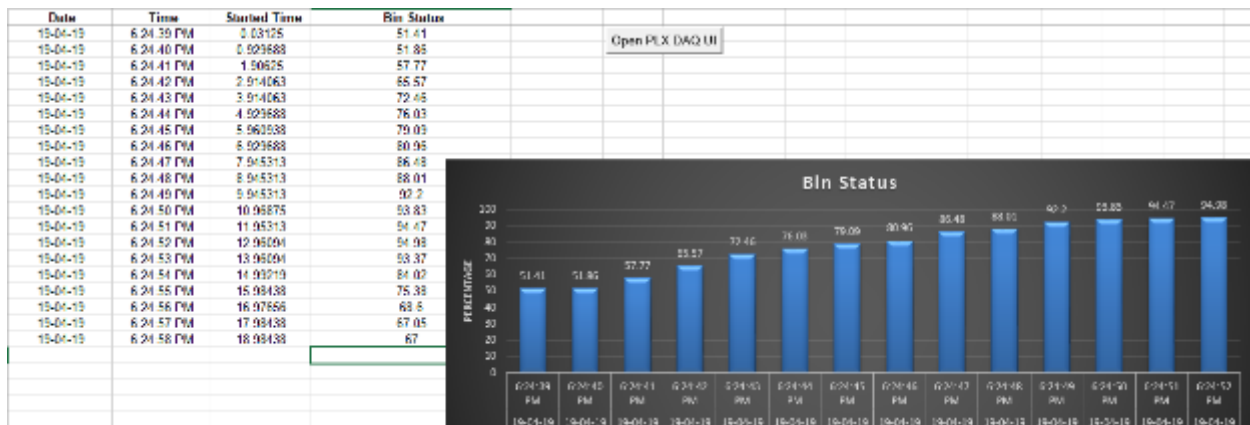


Figure 5-11: Bar chart: Plotting and graphing the data using PLX-DAQ

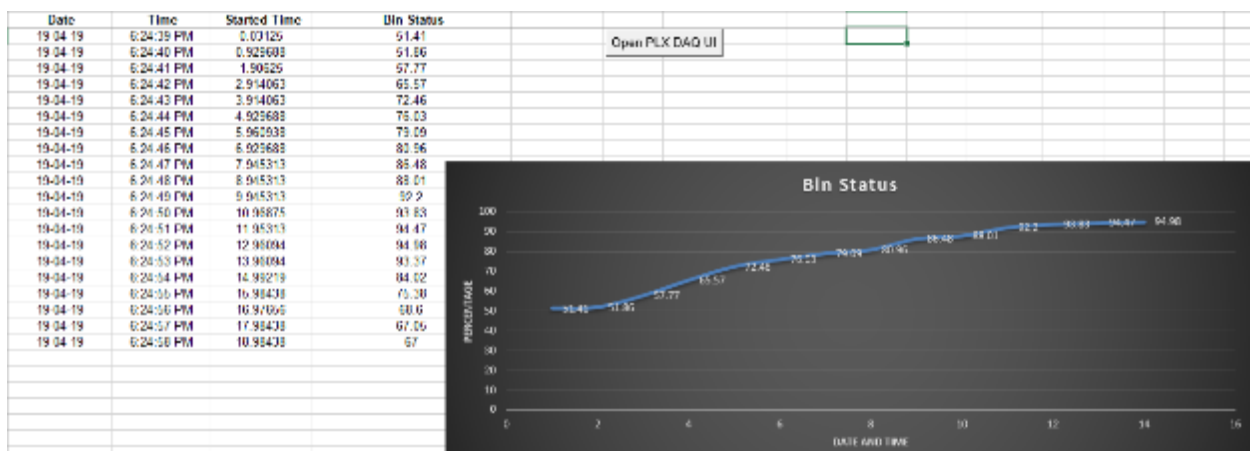


Figure 5-12: Scatter with smooth lines: Plotting and graphing the data using PLX-DAQ

Chapter 6: Conclusions and Recommendations

6.1 Conclusions

The Hospital uses the old traditional method of collecting the trash wheel bins therefore this means that the existing method of trash collection system in the Hospital is manual. The collection company assumes the fill level of the bins and the bins are cleaned on selected days weekly with an assumption that the bin is full. Feedback from the questionnaires has shown that there are a lot of undesirable bad effects on the environment.

This bad conditions includes among others, trash overflow, air and land pollution. This raised a concern to the public's care and safety to a more hygienic, clean environment. The findings from the questionnaires of the research study, also show the need for making collection on time, to overcome all the bad conditions brought by trash overflow.

The second research question on how effective is the current method of waste collection, is answered based on the responses from the questionnaires. The responses clearly shows that with the current waste management system, the collections are not made on time. This results in wheel bins spilling trash over the surface, as a result of over spilling bins people then turn to throw their own trash everywhere they are ,not using the bins provided to throw their trash hence they are full.

The third research question addresses the issues that are faced with the current system, majority of people show that there environment is unhygienic and dirty, bad ardor from rotten disposals especially from left-over foods. Dogs picking and scattering trash all over the environment, rats running over the trash and bins and flies swarming the bins caused by trash. Children also pick up on the dirt.

The dirty environment causes a lot of health problems, there are issues of land and air pollution. The bad odor inhaled by children causes respiratory diseases, dirt picked up transmits diseases from one person to another through contact.

The solution of the researcher makes use of a smart bin management system. The smart bin is sensor-based, the Ultrasonic sensor is used for distance measure and monitoring of bin fill-level. This implementation of smart bin collection uses, ultrasonic sensor, the Arduino board, solderless breadboard and jumpers for circuit connection. The data is collected and conveyed to the control room officials on the computer via Arduino-to-excel communication.

The connection is made via PLX-QAX excel spreadsheet to monitor the status of the bin and once the bin reaches above the fill-level, the arrangements to clean the bin is made. If the dustbin is not cleaned in specific time, the authorities also has access to the Arduino-to-excel communication hence the collectors can and will not lie about the data and collections made. Therefore if the bin is not collected on time the collecting company will not be generate fake reports.

The use of a smart bin is an automated process that achieves real time data on the PLX-DAQ excel spreadsheet. The Arduino-to-excel communication helps collectors to get with prior information to the status of the bin, therefore the authorities are able to make informed decisions about collection times to save fuel consumption with scheduled visits to the hospital to collect. This greatly decreases the number in travelling up and down the collection sites when the bins are not full. This automatically reduces the costs of fuel in regards to the reduced trips to and from the collection site.

The continual monitoring of the status of the bin helps to keep the environment clean and healthy for the public. The collections are made on time, the trash spilling over is mitigated, and the environment is left clean and hygienic with a minimal land and air pollution. The application of smart bin is efficient and effective use of waste collection.

This proposed smart bin functions on a real time data for collecting updating, analyzing and generating graphs and charts with the data then for keeping record, submitting work records and for future predictions to predict the next day of collection. The communication does not require any internet usage but of excel spreadsheet therefore the communication is not affected by any used of bad internet connection coverage, no service from the providers, and no high bandwidth problems, hence the communication is reliable, the data is always available when needed.

6.2 Recommendations

The observations of the researcher showed that sometimes the general waste gets mixed with hazardous waste as a results it is unsafe for the general waste collectors as they are not trained to collect hazardous. This research however does not address this issue. The researcher proposes the sensors to detect and separate hazardous from general waste for future improvement.

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Appendix A: Questionnaire

Dear Participant

This is an invitation to your favorable corporation to participate in the research study titled **“Application of Smart Waste Management System: Case Study Queen II Hospital”**. This study is fulfillment for Master’s Dissertation. I am presently enrolled Computer Systems Management though Distance Learning in Information Systems Faculty at Botho University, Botswana. The study intents to find out about the current status about the general waste collection in place at the Queen II Hospital. The objective of the research is to find solutions to waste overflow.

The questions are outlined with the determination of insight understanding about the current waste management and management approach to waste management currently employed in the Healthcare Centre, status of the environment, issues and problems encountered as a result of the current working system. Your response will help the Healthcare Center and all involved parties to find ways to a more improved waste management system.

Participants are not obligated to take part in the questionnaires, it is entirely up to the respondent to take part, which means your involvement is absolutely voluntary. A written consent of the participant will be provided. The entire questionnaire will take you an average of 15 to 20 minutes. The Questionnaires and interview answers will be completely confidential and strictly for

academic purpose. Each question has Instructions to follow. Please answer the questions in all conscience and provide truthful answers as best as you can.

Thanking you in advance for taking part, your effort is highly appreciated.

For any additional comments and queries, please feel free to contact me at makamohelo.mathe@botho.ac.bw or +266 59199758.

Sincerely, yours

Makamohelo Valentine Mathe

Questionnaires

Demographic Data

1. What is your name (optional): _____
2. Town/Village: _____
3. Date: ____/____/____

Please answer by placing a tick (✓) or a cross (x) in the correct box

Questions	Options	checkboxes
4. What is your age?	20 to 25	☐
	26 to 30	☐
	31 to 35	☐
	36 to 40	☐
	41 and above	☐
5. What is your Gender?	Male	☐
	Female	☐
	Other (specify)	☐
6. What is your Educational level?	No Schooling	☐
	Primary School	☐
	Secondary School	☐
	High School	☐
	Tertiary Education	☐
7. What is your employment status?	Government Employee	☐
	Own Business	☐
	Street Vendor	☐
	Student	☐

	Unemployed	☐ ☐ ☐ ☐ ☐
8. How often do you visit the Healthcare Centre?	Very often Often Occasionally Rarely	☐ ☐ ☐ ☐
9. How many hours do you normally spend at the Healthcare Center?	Less than an hour 1hr to 2hrs 2hr to 3hrs More than 3hrs	☐ ☐ ☐ ☐
10. Have you ever heard about waste management?	Yes No	☐ ☐
11. If yes, in what way	Over the radio Over TV In a public meeting In school	☐ ☐ ☐ ☐
12. Are you aware of any waste management at Queen II Hospital?	Yes No Not Sure	☐ ☐ ☐
13. How important is waste management to you?	Very important Important Somewhat important Not Important	☐ ☐ ☐ ☐
14. Do you think there is a problem with waste management at the Healthcare Centre?	Strongly agree Agree Undecided Disagree Strongly disagree	☐ ☐ ☐ ☐ ☐
15. Do you think there are enough waste bins available around the Healthcare Center?	Strongly agree Agree Undecided Disagree Strongly disagree	☐ ☐ ☐ ☐ ☐
16. How often do you notice the bins are over flowing with trash at the Healthcare Center?	Very frequently frequently Occasionally Rarely	

	Never	☐ ☐ ☐ ☐ ☐
17. How do you dump/ or dispose-off your waste?	Anywhere you are Alongside the garbage bins Putting it inside the garbage Others_____	☐ ☐ ☐ ☐
18. Do people dump their waste alongside the waste bins instead of putting it inside the bins?	Yes No	☐ ☐
19. Are you satisfied with the waste collection system in place?	Yes No Not Sure	☐ ☐ ☐
20. Is the environment clean?	Yes No	☐ ☐
21. What are the main problems with the Waste lying around?	Odor Rats Flies No problem Others_____	☐ ☐ ☐ ☐ ☐
22. What are you more concerned about?	Air pollution Water pollution Waste pollution Damage to scenic beauty Others_____	☐ ☐ ☐ ☐ ☐
23. What is your opinion on the current waste management system in the Healthcare Center	Bad Satisfactory Good very Bad	☐ ☐ ☐ ☐
24. What is the main reason for your level of satisfaction/dissatisfaction?	Unreliability Improper collection Reliable Cooperative Others_____	☐ ☐ ☐ ☐ ☐
25. How concerned are you with the health center environment	Concerned Not concerned	☐ ☐
26. How concerned are you with the health impact of waste	Concerned Not concerned	☐ ☐
	Yes	

27. Would you say the waste management is a major issue currently affecting Queen II Hospital Yes/ No	No	☐ ☐
28. Do you believe waste can be properly maintained?	Yes	☐
	No	☐
	Not Maintained	☐
29. How important is it that there is a proper waste management?	Very important	☐
	Important	☐
	Somewhat important	☐
	Not Important	☐

30. Please explain why the waste management is important to you

.....

.....

31. What do you suggest the authorities do to resolve the improve the waste problem

.....

.....

Consent Form for Questionnaires

- I the undersigned, I have read and understood the conditions, the purpose and objectives of the research study.
- I have been given the right to ask question by the researcher.
- I understand that the information I provide will be used solely for the educational and research purposes.
- I understand I have an option to not to answer certain questions, that at any time, I can skip questions, without being asked why.
- Confidentiality of All information collected from the questionnaires will be protected at all cost. Identification of the respondent will be anonymous.
- All information I provide as part of the questionnaire and not mentioned in the dissertation will be destroyed at the end of the research study.

Respondent's signature: _____

Date: _____

Researcher's signature: _____

Date: _____

Appendix B: Interview Questions

Sample Interview Questions

1. What is Waste management?
2. Please explain why the waste management is important to you?
3. What is the method that is currently being used at the Hospital?
4. Do you think there is enough dustbins around the hospital?
5. How many Wheel Bins are available outside?
6. How many times do the collection company comes in to collect the Wheel Bins?
7. Do sometimes wheel bins overflow with trash?
8. Is the Hospital environment always clean?
9. Do you think they are enough Wheel Bins for trash collected daily?
10. Are you satisfied with the current waste management system?
11. What problems are encountered with the trash overflow?
12. What are the health issues associated with the problems of trash overflow?
13. How do you think can be the solution to the problem brought by waste management?