LOCATION BASED GARBAGE MANAGEMENT SYSTEM WITH IOT FOR SMART CITY

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Bachelor of Science Special Honors Degree in Information Technology
(Specialized in Computer System & Networking Engineering)

Department of Information Systems Engineering

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(Dissertation submitted in partial fulfilment of the requirement for the Degree of Bachelor of Science Special (honors) In Information Technology)

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DECLARATION

We declare that this is our own work and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of our knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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The supervisor/s should certify the proposal report with the following declaration.
The above candidates are carrying out research for the undergraduate Dissertation under my supervision.

…......................................   …….................................

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ABSTRACT

Smart cities integrate multiple ICT and IOT solutions to build a comfortable human habitation. One of these solutions is to provide an environmentally friendly, efficient and effective garbage management system.

The current garbage collection system includes routine garbage trucks doing rounds daily or weekly, which not only doesn't cover every zone of the city, but is a complete inefficient use of government resources.

This paper proposes a cost-effective IOT based system for the government to utilize available resources to efficiently manage the overwhelming amounts of garbage collected each day, while also providing a better solution for the inconvenience of garbage disposal for the citizens.

This is implemented as a network of garbage bin which integrates cloud based techniques to monitor and analyze data collected to provide predictive routes generated through our algorithm for garbage trucks. An android app is developed for the workforce and the citizens, which provides the generated routes for the workforce and finds the nearest available garbage bin for citizens.

Keywords – IOT; Smart City; Wi-Fi; Predictive Analytics; Data mining; MSW

ACKNOWLEDGEMENT

We would like to express my special thanks of gratitude to our project supervisor, Ms.Shashika Lokuliyana for her patient guidance, and useful critique of our research work. Her willingness to give her time, so generously has been very much appreciated. Especially mentioning the moral support and the continuous guidance by providing important feedback enabled us to complete our work successfully. We would also like to thank our lecturer-in-charge, Mr. Jayantha Amararachchi for constantly providing us with the guidance and assistance to carry out the research successfully. Also, we would like to thank all the other friends who supported us and encouraged us throughout this project.

Finally, we would like to express our special thanks to our parents for their support and encouragement throughout our studies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Workforce User	The person who actually uses a particular android application to collect garbage. (Cleaners)
GPS	Global Positioning System
IoT	Internet of Things
Author	Person submitting an article to be reviewed
Bin	Garbage bin
API	application programming interfaces
MSW	Municipal Solid Waste
Wifi	Technology for wireless local area networking with devices based on IEEE 802.11 standards
Raspberry pi zero	Tiny and affordable computer that use to implement garbage functionalities
Python	High level language programming language that can be used to build the code of the system
Garbage Level	Trash can fill measurement
GUI	Graphical User Interface
SSH	Secure Shell
CLI	Command Line Interface
GPIO	General Purpose Input Output
GSM	Global System for Mobile
Debian	Unix-like computer operating system that is composed entirely of free software

1.0 INTRODUCTION

1.1 Background Context

Proper waste management is a basic requirement in any kind of an environment. city Usually cleaning is done in two or three times per day in urban. As an urban city like Colombo usually there are about 1,200,000 to 1,500,000 [1][2] employees heading for their workstations every morning. For all those people there are just not enough garbage bins available. On the streets of urban cities hundreds of people are passing the same location in short time period. most people are carrying food covers, polythene bags and plastic bottles. If they dispose all them at once, the bins will be filled in several minutes. When they fill up people just litter their trash around the garbage bins because there is nowhere else to put them. Also considering fill level of garbage bin, all garbage bins are not filled equal time period. Some garbage bin will be filled quickly and some garbage bins will be filled slowly. While collecting garbage by trucks are covered that all type of garbage bin. The obvious solution to this is for the cleaning staff to stay near garbage bins everyday till they fill up to clean them or garbage collecting trucks should go around in the city regularly. These are not effective and efficient solution. It takes way more cleaning staff and costs a lot of money. it is not practical. The same scenario is happening in workstations. For instance, a bank or a government office cafeteria usually has about five to six garbage bins to serve hundreds of employees. This is simply not enough.

There are some notable negative effects when considering the garbage bins always being full. One of the main effects is the surrounding area starting to smell and be very unpleasant. When the garbage bins are full people put their trash on sides of the garbage bins. When this is done for some time, first it starts to smell bad. So, others who come later tend not to go close and throw their trash in the direction of the garbage bins. If there are any leftover food items, throwing it causes them to spill. This attracts animals like cats, dogs and flies. And these animals spill them even more. Another negative effect is the diseases that spread. It’s not just the garbage that spread them, but the animals also can be a source.

1.2 Literature Survey

1.2.1 Smart Bin Implementation for Smart Cities (2015) [3]

This research is focused on creating optimal changes in the conventional methodology of waste collection. This is done by creating a smart bin that will upload the fill levels via SMS. SMS received from the GSM modules of the dustbin is taken in the form of text files. The text file is connected to the excel sheets. The updated values of the dustbin level are taken to form a real time smart bin status. The excel application designed creates a real-time dashboard along with a time series graph which shows the current trend as well as the historical trend of waste level in that particular smart bin. The data collected is then analyzed to predict when specific bins gets filled up in the future.

1.2.2 Cruisers: A Public Automotive Sensing Platform for Smart Cities (2016) [4]

This research introduces Cruisers, an automotive sensing platform for smart cities, which is developed based on the following ideas.

- Garbage collecting trucks are used as host automobiles to accommodate sensors
- 3G cellular communication network is used to wirelessly deliver sensed data directly to servers
- Proxy servers are adopted to convert the format of sensed data to required ones.

The technology consists of a collection of sensor nodes installed into the same number of garbage collecting trucks, one proxy server and one data server. Java program is developed to control the sensor nodes. An iOS application is also developed to demonstrate the sensing process and the covered area.

1.2.3 IOT Based Solid Waste Management System A conceptual approach with an architectural solution as a smart city application (2016) [5]

This paper aims at providing an IOT based solution to solve the problems faced by the present solid waste management system. By building an IOT based system, solid waste can be tracked, collected, and managed easily by automating and monitoring. Sensor data collected from the garbage bins can be sent to a gateway using LoRa technology. Data from various garbage bins are collected by the gateway and sent to the cloud over the Internet using the MQTT (Message Queue Telemetry Transport) protocol. The main advantage of this system is the use of LoRa technology for data communication which enables long distance data transmission along with low power consumption. They use the data collected to analyze and generate reports on the amount of garbage collected and the types of garbage collected.

1.2.4 Top–k Query based Dynamic Scheduling for IOT-enabled Smart City Waste Collection (2015) [6]

This paper proposes a system architecture to achieve dynamic waste collection and delivery to processing plants. This is done using a top-k query based dynamic scheduling model. In implementation the Smart City is divided into multiple sectors which cover the entire city area. Each sector contains a number of multiple intermediate waste depots, which are temporary waste storage areas. Further waste processing is done on garbage tips located at the edge of the city. Low capacity garbage trucks are used to collect garbage from bins and store them in waste depots. High capacity garbage trucks are used to transfer the garbage from garbage depots to garbage tips. Cloud middleware collects sensor data and provide them to the system. Dynamic scheduling algorithm (Figure 1.2.4.1) is used to locate the first available truck which can load waste from the filled bins. A route for the truck is created according to the gathered information using top-k query.

TABLE I. DYNAMIC SCHEDULING ALGORITHM

Input: *Bins*
Output: *k*
While (*true*) **Do**
    k = top−*k* query from relation *Bins*
    /*Select *k* *red* bins to load*/
End While

Figure 1.2.4.1: Dynamic Scheduling Algorithm

1.2.5 Cloud Computing Based Smart Garbage Monitoring System (2016) [7]

In this paper, a Smart Bin is proposed with a network of dustbins which integrates the idea of IOT with Wireless Sensor Networks. They also propose a concept of a network of smart garbage bins based on the Stack Based Front End approach of integrating Wireless Sensor Network with the Cloud computing and discuss how Machine Learning techniques like Decision Forest Regression can be applied to the sensor data leveraged by the system to gain useful insights to improve the efficiency of the garbage monitoring. The system overview (Figure 1.2.5.1) is displayed below.

Hardware used:

- WSN Motes
- IRIS
- Ultrasonic sensors

Software used:

- TinyOs-2.1.2
- NesC
- Azure IOT Hub

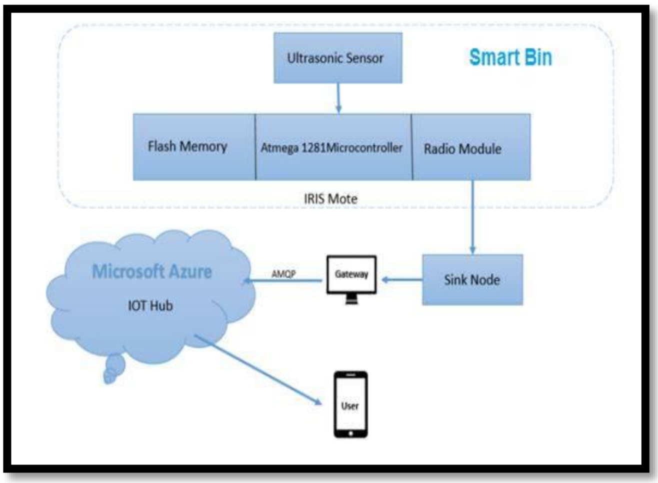

Figure 1.2.5.1: System Overview

This paper uses Azure Machine Learning web service to deploy a trained model as a predictive web service. This system predicts which garbage bins fill up at which points in time.

1.2.6 IOT Based Smart Garbage alert system using Arduino UNO (2016) [8]

This paper proposes a smart alert system for garbage clearance by giving an alert signal to the municipal web server for instant cleaning of dustbin with proper verification based on level of garbage filling. The development board used is an Arduino UNO. The process involved is ultrasonic sensors checking garbage bin levels and sending it to the municipal council. After cleaning the dustbin, the driver confirms that the task is complete using a RFID Tag. After the cleaning is verified, the information is sent to the server.

An Android application is developed and linked to a web server to send the alerts and remote monitor worker progress. The notifications are sent to the Android application using Wi-Fi module.

The e-monitoring system has two parts:

• Embedded system: It comprises of an RFID reader, a microcontroller, a Liquid Crystal Display (LCD) and a GPRS segment.

• Web based software system Interface: It comprises of a GPRS module, a Central Server, a Database Server and a Web server. The Figure reveals the block diagram of the web centered software system.

1.2.7 Solid Waste Management Architecture using Wireless Sensor Network Technology (2012) [9]

This paper is focused on the on-site handling and storage processes and on the transfer process, with the main topic at developing a smart solid waste management system capable to ensure the public health with costs reduction and quality improvement. In order to enhance the efficiency of solid wastes on-site collection and transfer, an innovative solution for the monitoring and management system has been proposed. A

Wireless Sensor Network (WSN) has been developed to improve the garbage bins monitoring process.

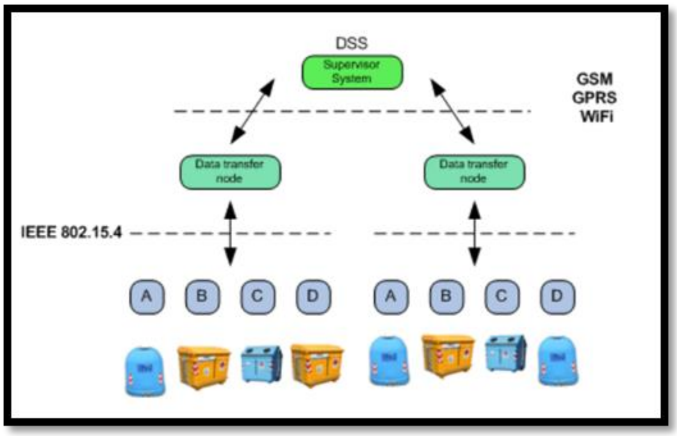

Figure 1.2.7.1: SEA project system architecture

The main components of the developed architecture on the SEA project (Figure 1.2.7.1) are decomposed into three layers. Starting from the bottom, the garbage bins reside at the first one, the DTNs at the second one and the supervisor system at the third one.

- The first layer is composed by sensor nodes, which need for the filling monitoring and provide short-range transmissions through RF technology.
- The second layer is composed by communication modules, which provide long-range transmission through GSM/GPRS.
- The third layer is composed by servers, which provide data storage and supervisor modules.

Most research papers have implemented garbage management system, but they lack several key features. This paper introduces an Implementation of Automated Management System for an Optimized Waste Collection System.

Most of the other papers has used cloud based systems to analyze and monitor data. We find no error in doing so as this is the best method to do this currently. So, we have also taken the cloud based approach.

Cloud Computing Based Smart Garbage Monitoring System [7], Smart Bin Implementation for Smart Cities [3] has used an android application to notify cleaners, a Cloud Computing Based Smart Garbage Monitoring System [7] has used windows application and some uses only SMS notifications. This project improves upon this to give notifications through the android application for better efficiency.

Though most papers have focused on optimizing garbage collection, based on research papers mentioned the methods proposed on this paper is better than most of the algorithms the above-mentioned papers provide.

- Cloud Computing Based Smart Garbage Monitoring System proposes a route calculation between only two static points [7].
- Cruisers: A Public Automotive Sensing Platform for Smart Cities has used a method that divides the city into sectors, this method can waste fuel and time [4].

The method proposed on this paper is a predictive system that predicts and clean bins that reaches certain levels even before they reach it.

1.3 Research Problem

At present, solid waste management in Sri Lanka is not at an adequate level. Municipal councils of urban cities only collect a small portion of the total waste generated. Referring to the National Solid Waste Management Report for 2007 of the Japan International Cooperation Agency [10], the total amount of garbage collected in 311 local authorities was 2838 metric tons per day [10], which amounts to an annual garbage collection of 1.04 million metric tons per year. This is only 23% [11] of the total garbage generated Colombo District. This means that nearly ¾ of the garbage generated leads to surface and groundwater pollution.

With this much waste generated and no way of collecting them, garbage bins fill up instantly. This leads to people turning to open waste dumping. Open waste dumping is the main source of all of the below mentioned problems.

- Increase of acidic levels of ground water, which is water pollution.
- Buildup of greenhouse gases such as methane and carbon dioxide, leading to air pollution and climate change.
- Loss of wetland habitats
- Spread of diseases such as Dengue fever, malaria, etc.
- Attraction of wild animals

In spite of the statistics mentioned above, Sri Lankan government spends a substantial amount of money on solid waste management. An estimation made in 2004 revealed that solid waste management expenditure ranges from a high Rs. 2000 per metric ton in a Municipal Council to a low Rs. 1,200 per metric ton in an Urban Council. So, it could be estimated that Sri Lankan government spends an amount between 1.2 to 2 billion rupees [11] on daily collection and disposal of garbage.

1.4 Research Gap

Most research papers have implemented garbage bins, but they lack several key features. This paper introduces an Implementation of Automated Management System for an Optimized Waste Collection System.

IOT Based Smart Garbage alert system using Arduino UNO has used an arduino board, this poses problems because arduino does not support multi-threaded programming [12]. To avoid this Raspberry pie zero development board is implemented, which is about the same price as the Arduino Uno and supports multithreaded programming.
Most of the papers have used only one level measuring sensor in their bins. This poses a problem because garbage levels can be at different levels at different areas of the bin. To avoid this, four sensors are implemented which will be much more accurate at reading the actual level of the garbage level.

Different research papers have used different methods to transfer data from the bin.

- Smart Bin Implementation for Smart Cities has used GSM technology [3].
- Cruisers: A Public Automotive Sensing Platform for Smart Cities has used GSM technology [4].
- IoT Based Solid Waste Management System A conceptual approach with an architectural solution as a smart city application has used LORA technology [5].
- IOT Based Smart Garbage alert system using Arduino UNO [8] has used Wi-Fi
- Solid Waste Management Architecture using Wireless Sensor Network technology [9] has used RF and GSM technology

Most of these papers has used GSM technology. When using GSM there is the hassle of through registering to a subscriber and has to pay for the services. For this project Wi-Fi was chosen due to the fact that in a smart city everything would be connected through Wi-Fi. So, this system can easily integrate with the existing communication system.

In Addition to the technologies mentioned, this proposed system will contain these following functions:

- A hand gesture system to open and close the bin door
- An auto lock feature to lock the bin at 100% capacity

After the sensor data has been transferred different papers have used different methods to manipulate data,

Smart Bin Implementation for Smart Cities [3] has used an Excel application, which has some weaknesses such as

- Vulnerable to fraud
- Susceptible to trivial human errors
- Difficult to troubleshoot or test
- Obstructive to regulatory compliance
- Not designed for collaborative work

Most of the other papers has used cloud based systems to analyze and monitor data. There is no error in doing so as this is the best method to do this currently. So This paper has also taken the cloud based approach.

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The method proposed on this paper is a predictive system that predicts and clean bins that reaches certain levels even before they reach it.

1.5 Research Objective

1.5.1 Main Objectives

- Build a cost-effective garbage management system for the municipal council that will help them keep the city a cleaner place.
- Build a system (Garbage bin/ android application/ website) that will encourage people to use garbage bins instead of littering.

1.5.2 Specific Objectives

The specific objectives are:

- Build a website and client application that inspires clients to use the system, gives proper knowledge on how to use the system and integrate it into their day to day lives.
- Give the government an estimate of the profit to be gained from recycling the amount of garbage collected from each region. Give incentive for the government to setup more recycling stations.
- Give the government statistical values of how much of specific types of materials, such as plastic, glass, etc, is being used in each region.
- Give the government the foundation statistics to implement techniques to reduce the use of non-ecofriendly materials like plastic and have a way to test if the implemented techniques are successful.
- Provide an intelligent feedback analytical system to provide better service to users.
- Build a more user friendly, user attractive trash can which can be used to motivate the citizens to use it more often.
- Give alerts and warning when there is an error without using human inspections which will reduce the needed number of workforce employees.

2.0 METHODOLOGY

2.1 Methodology

2.1.1 Setting up the Garbage bin

Embedded hardware devices are being use for assemble a garbage bin. With the help of the embedded devices bins can perform the earlier mention functions. For the implemented bin following hardware devices will be used.

- Development Board
- Distance level measure sensors
- Motion sensors and motors

2.1.2 Hand Gesture System

When the lid of the bin covered with dirt people are lacking to use that lid to open the garbage bin. Instead of putting the garbage into the bin users are try to open dump the garbage near the bins. The Implemented System it will improve the user attraction to use the bins frequently by opening the bins' lid by a simple hand gesture.

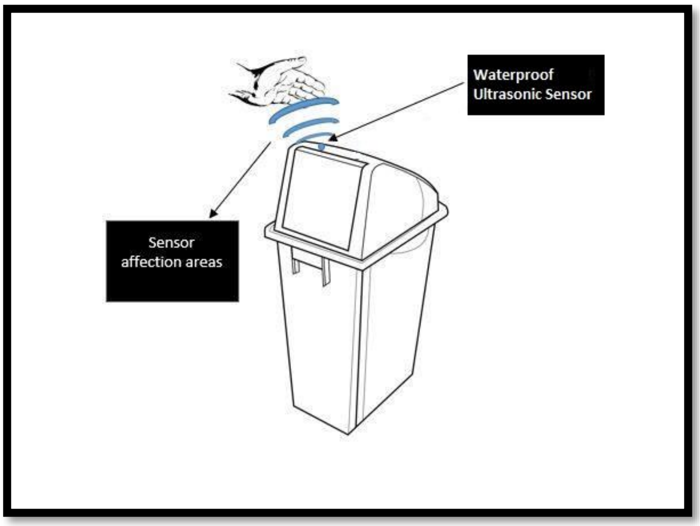

Figure 2.1.2.1: Front view of the bin

As shown in Figure 2.1.2.1 a simple hand gesture user can open the bin and after putting the garbage into the bin user can close the bin with the same hand gesture. If user forgets to close the bin after opening bin will automatically close the bin 30 second later after the opening time.

Opening and closing of the lid is done by the servo motor. When the sensor detects the servo motor rotates 90º (opening the lid). When the right sensor detects servo motor rotates back the 90º to 0º (closing the lid).

Without using a normal ultrasonic sensor bin is integrated with a waterproof ultrasonic sensor to work in any environment and climate.

2.1.3 Garbage Level Measurement System

Garbage level detection is done by two ultrasonic sensors. These sensors are fix to bin shown as figure 2.1.3.1.

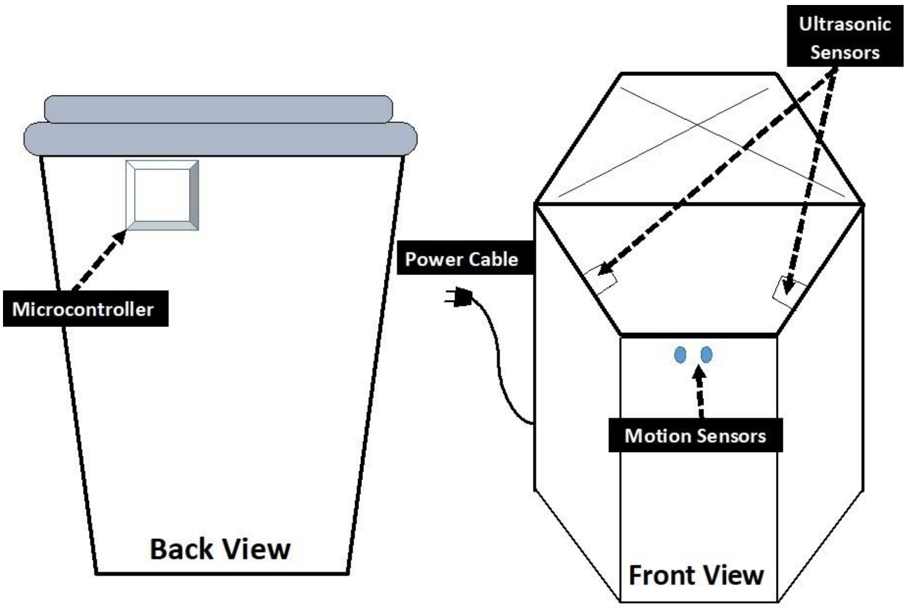

Figure 2.1.3.1: Bin Architecture

Each sensor is calculating the distance to garbage from the sensor mounted location. This distance has to subtract by the height of the garbage bin, divide it by height of the garbage bin and multiply by 100 for percentage value of the current garbage level.

$$\boldsymbol{Garbage\ level} = \frac{height\ of\ the\ garbage\ bin - \ Sensor\ measured\ distance}{height\ of\ the\ garbage\ bin} \times 100$$

This calculation is doing before sending the garbage level to the hosted server database. Garbage level is determined for each time when the lid of the bin is opened and closed. With the hand gesture system, it will be closed the lid each time even the user forgets to close the lid. Performing calculations on specific times will help to utilize the processing power of the development board.

After calculating the garbage level, it will send the calculated value specific field in the table that is included in the database where the cloud server hosted. Uploading the data to the server will be done by the inbuilt Wi-Fi adapter on the raspberry pi zero W and each bin have to connect to internet using this adapter. Data is uploaded to the server only when a client uses a bin. This will reduce the data traffic and reducing the database's public network connectivity. Database should grant privileges for incoming database connection request from the raspberry pi zero w. For each bin there is only one field to represent the garbage level even there are two sensors because these two sensors calculated garbage level to their own measured values, get the average of the two calculated values and upload that averaged garbage level to the database as shown in figure 2.1.3.2.

←T→		binID	areaName	areaID	filedLevel	latitude	longitude	Status
	Edit Copy Delete	MLB-10-PA	Malabe	MLB	45.3527311906747	6.914757	79.972827	Active

Figure 2.1.3.2: Uploaded garbage level

2.1.4 Safety System

When workforce staff come to clean the bins, there should be an option to disable the sensors in the bin until the cleaning process is over.

For this, a solution has developed using the workforce application. Workforce application is the main interface where the workforce staff always interact. As show in figure 2.1.4.1 a toggle switch button was developed to disable the all the sensors in the smart trash can.

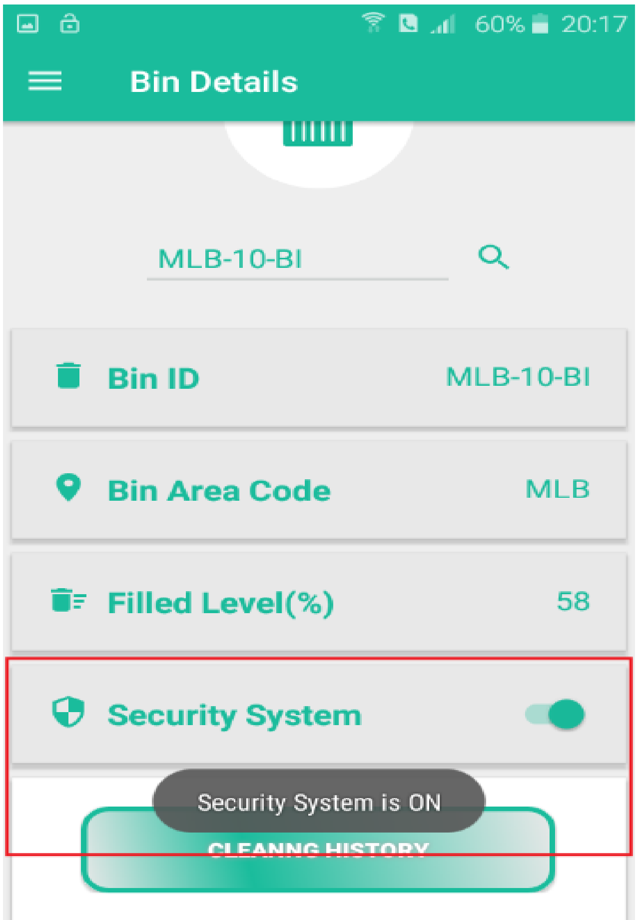

Figure 2.1.4.1: Safety button on Workforce Application

Enabling this toggle button will disable the all the running processes which includes hand gesture system and the garbage level measurement processes. When a workforce employee has to clean a bin he/she have toggle this button to mode ON and start their cleaning process. After cleaning is done he/she has to disable the safety system to make the trash can operational.

If there is an error found with a trash can operational status can be disable from any this option until the trash can fixed.

2.1.5 Statistical Fault Detection

Calculated garbage level is the most important information in whole system. If there is an error in the calculated garbage level it will breakdown the whole system. Garbage level is calculated by the ultrasonic distance measurements. There is no mechanical way to check these measurements are true. Because of that creating a statistical fault detection model is the best approach to overcome this problem.

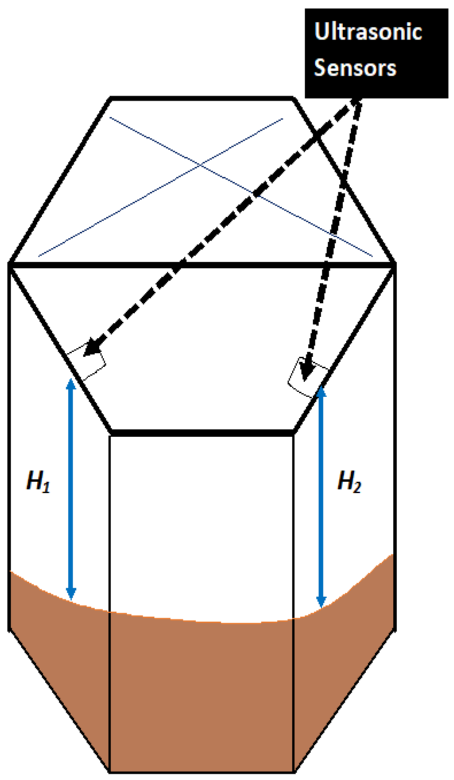

Figure 2.1.2.1: An operational bin

H_1 - Ultrasonic sensor1 (S_1) measured distance

H_2 - Ultrasonic sensor2 (S_2) measured distance

$time\ (t) = t_i$

$G_i \ \rightarrow\ Calculated\ garbage\ level$

<u>At $t = t_1$,</u>

$$|H_1 - H_2| \leq \alpha$$

$\alpha \ \rightarrow\ Confidence\ Factor$

Confidence Factor is a hypothetical value where the hypothesis is S_1 and S_2 operates without any errors. Confidence factor is determined by testing the trash can under various conditions and observing the visible garbage level and the measured garbage level.

<u>If at $t = t_2$,</u>

$$|H_1 - H_2| > \alpha$$

Check the garbage levels of the previous 5 weeks at the, $time = t_2$;

$Garbage\ level\ on\ 1^{st}\ week\ \rightarrow G_1$

$Garbage\ level\ on\ 2^{nd}\ week\ \rightarrow G_2$

$Garbage\ level\ on\ 3^{rd}\ week\ \rightarrow G_3$

$Garbage\ level\ on\ 4^{th}\ week\ \rightarrow G_4$

$Garbage\ level\ on\ 5^{th}\ week\ \rightarrow G_5$

$G_i \ \pm\ \beta\ ;\ \{i = 1,2,3,4,5\}$

$\beta\ \rightarrow Range\ Factor$

Range factor is determined by taking a large sample size of S_1 and S_2 measured distances and taking the average difference.

If $G_i \pm \beta \rightarrow$ *is in the range three, four or five previous weeks*

- Ignore the S_1 and S_2 deviation. Both sensors are working properly.

If $G_i \pm \beta \rightarrow$ *is not in the range three, four or five previous weeks*

- Anomaly detected. Notify administrator about the sensor fault through the monitoring dashboard.

2.1.6 Setting up the Server

Amazon AWS was selected to purchase a VPS that suits the specific requirements of the project. The Figure 2.1.6.1 displays the different servers available.

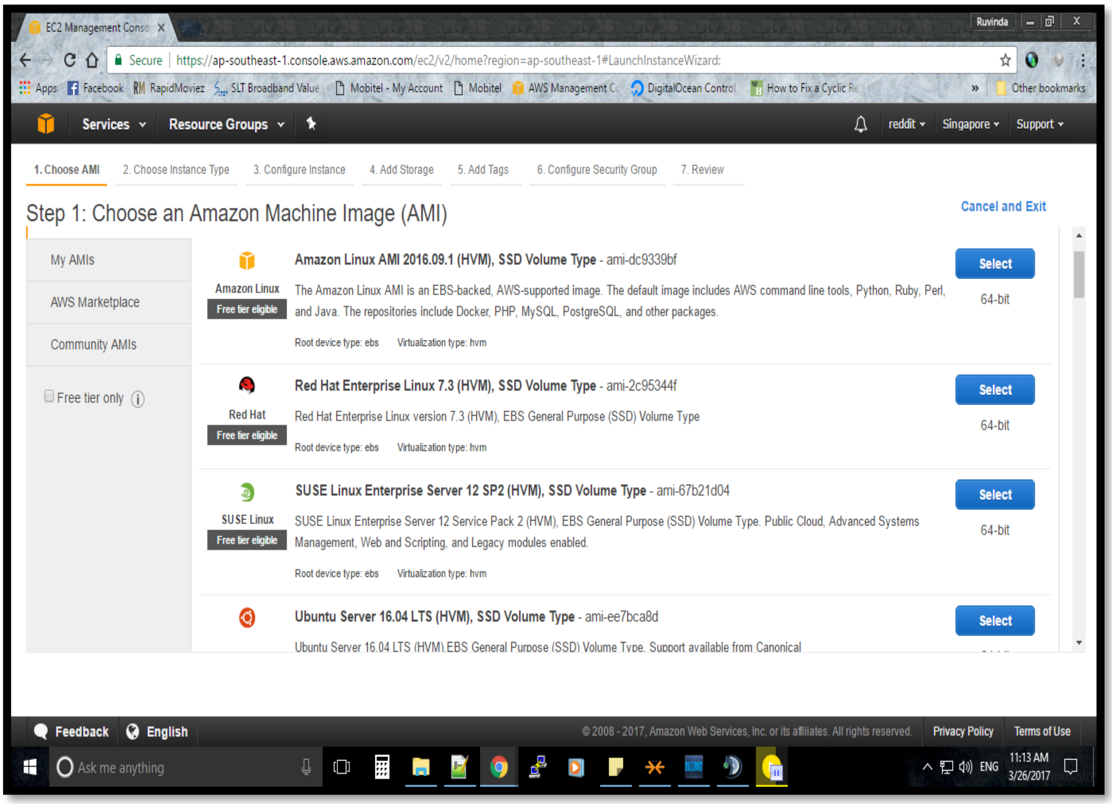

Figure 2.1.6.1: AmazonAWS

Once the VPS was bought these are the software that was used to setup the server and website.

Table 2.1.6.1: Software to be used

Software	Task
Puttygen	To create private key
Putty	To connect to VPS
WinSCP	FTP client to transfer files
LAMP server	Package includes : Apache web server : MySQL database : PHP language

2.1.7 The Website

2.1.7.1 The Home Page

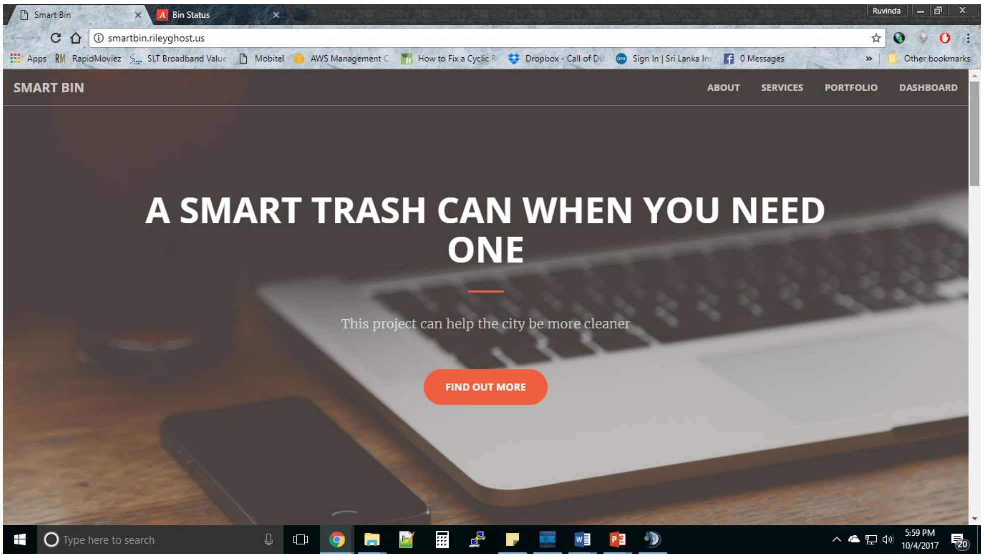

Figure 2.17.1.1: Home Page

The home page is where the first page displayed when a user accesses the website, this user can be an Admin or a client.

This page contains a number of sections:

- Find out more

  This section contains information and knowledge needed to inspire a new client to start using the system, as well as information on how the system works.
- Services

  This section provides information about the services provided by the system
- About

  This section contains information on how to get in contact with our system administrators and managers.
- Dashboard

  This section contains the link to the sign-in page for the admins and the clients.

2.1.7.2 The Sign-in Page

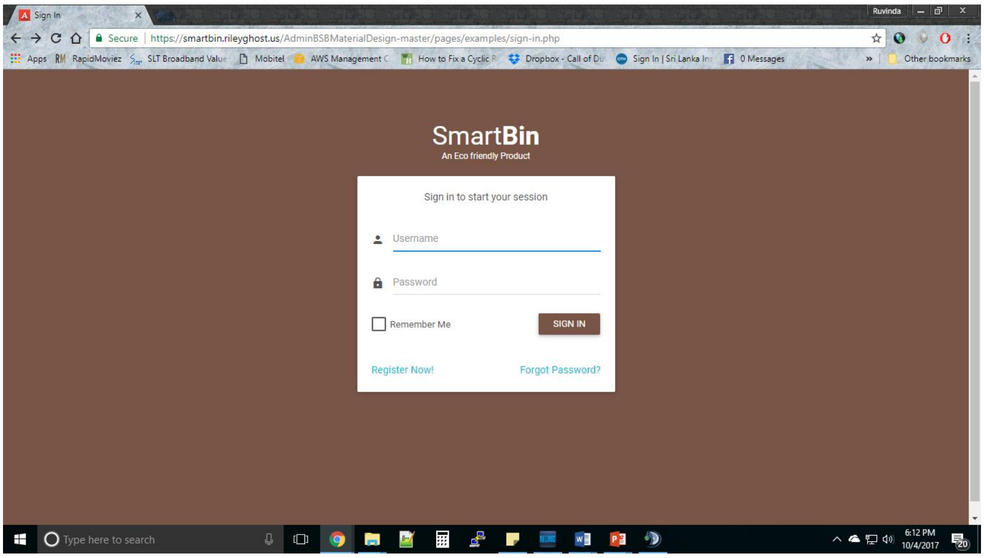

Figure 2.1.7.2.1: Sign-In Page

This page is used by the clients and the admins to login to their respective dashboards. Based on the login credentials provided the user is directed to the Admin dashboard or the Client dashboard.

2.1.7.3 The Sign-up Page

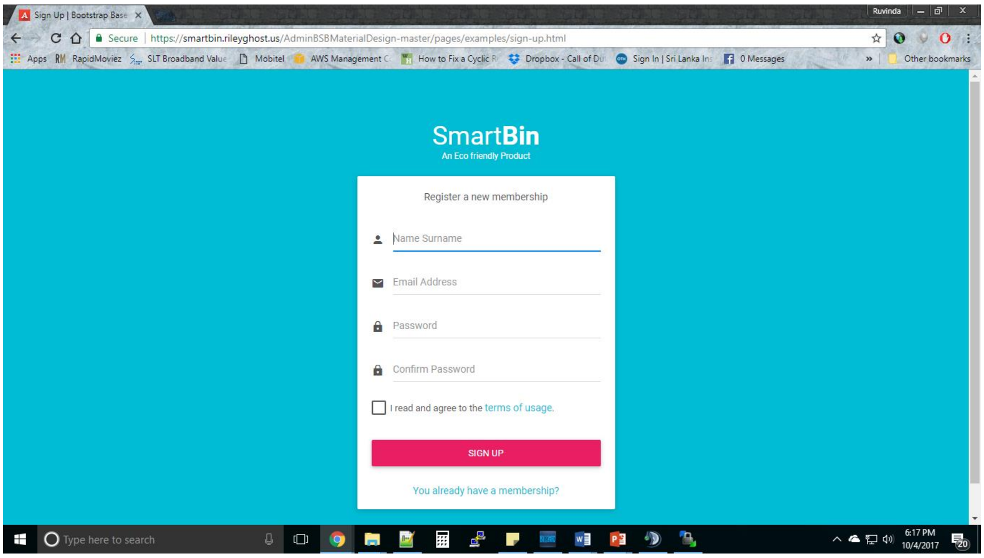

Figure 2.1.7.3.1: Sign-up Page

This page can only be used by new clients to register on the system. This cannot be used to create new administrator account. Only logged in administrators have permission to create new administrator accounts from the Admin dashboard itself.

2.1.7.4 The Admin Dashboard

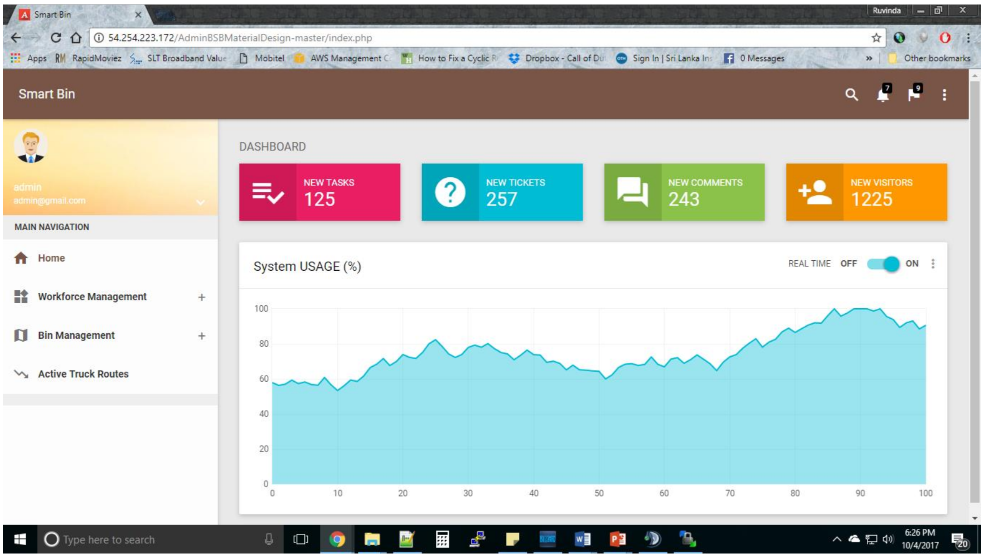

Figure 2.1.7.4.1: Admin Dashboard

This is the dashboard which the admin has to access to gain access to all control functions of the system. The available functions are as follows;

- Add, Delete and manage Administrator accounts
  For security reasons users are not allowed to register themselves as admins. The website signup page can only be used to register new clients. If a new administrator account has to be created, it can only be done by another administrator.
- Add, Delete and manage Workforce user accounts
  Workforce users does not have access to the website, they only have access to the Workforce android application. Since workforce users only has access to manage their profile from the android application an administrator has to create new accounts for workforce users. If a workforce user is no longer in service, the administrator has access to remove the account.
- View Active Truck Routes
  The admin has the capability to see the active truck routes in each region
- Status of bins and location
  The admin has the capability to see all the statuses of bins in each region and their locations on a map

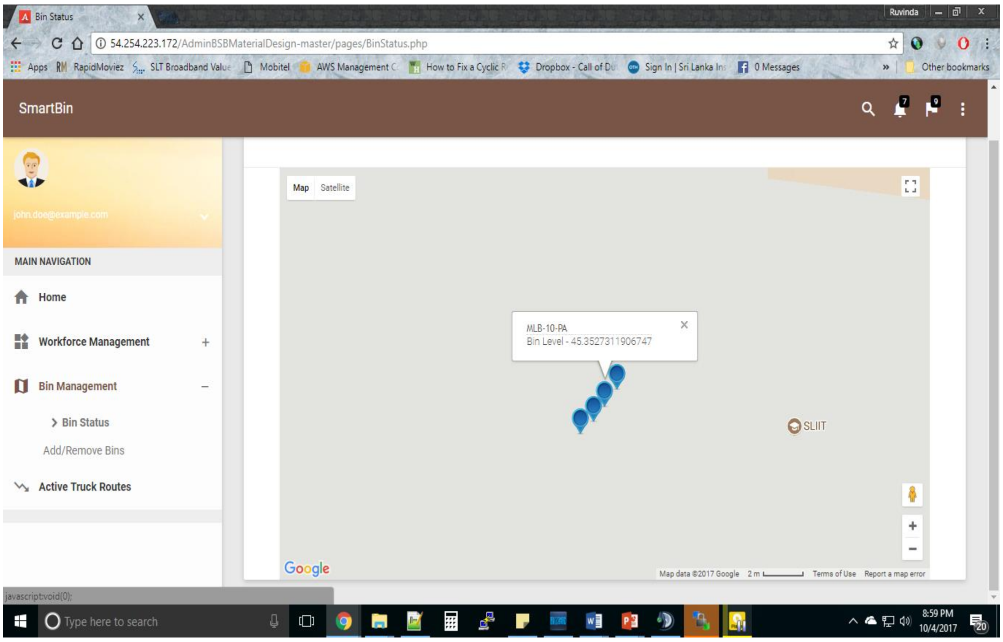

Figure 2.1.7.4.2: Status of bins

- Add, remove bins and change status of bins
  The admin has the capability to manage bins on a map itself. That is add a new bin, remove a current bin or change the status of a bin to 'Active' or 'Inactive'.

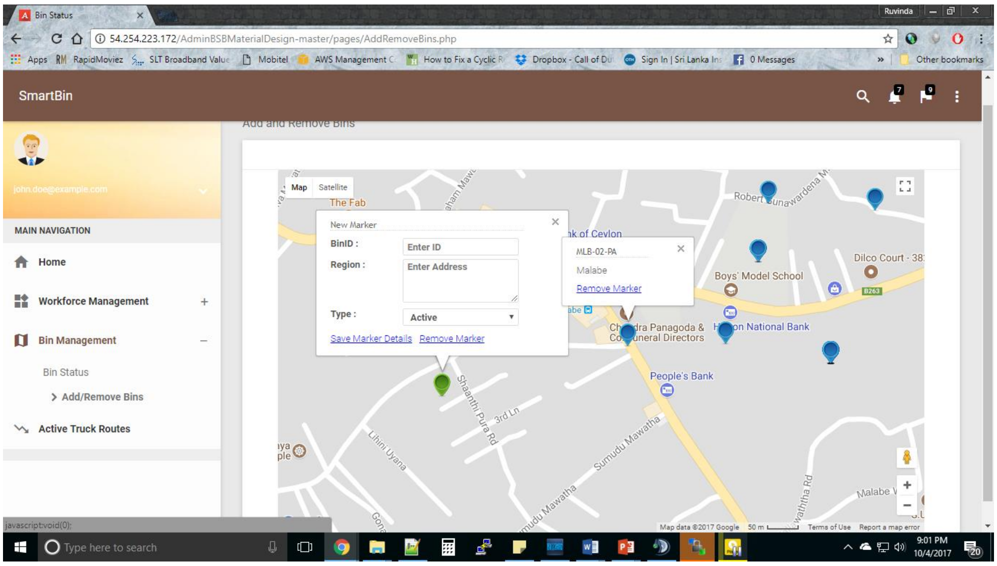

Figure 2.1.7.4.3: Add/Remove Bins

- View client requested bins
  The admin has the capability to view client requested bins and add them if needed from the add bin map.
- View Reports
  The admin has the capability to view different statistical reports generated by the system, such as:
  - Amount of garbage collected in each region from the types biodegradable, plastic, paper and glass.
  - Profit that could be gained by recycling the specific weights of garbage collected from each region.
- Add news and maintenance alerts
  The admin has the capability to add news such as new features added to the system and maintenance updates to the news feed that is shown on the website for clients and the Client android application.

2.1.7.5 The Client Dashboard

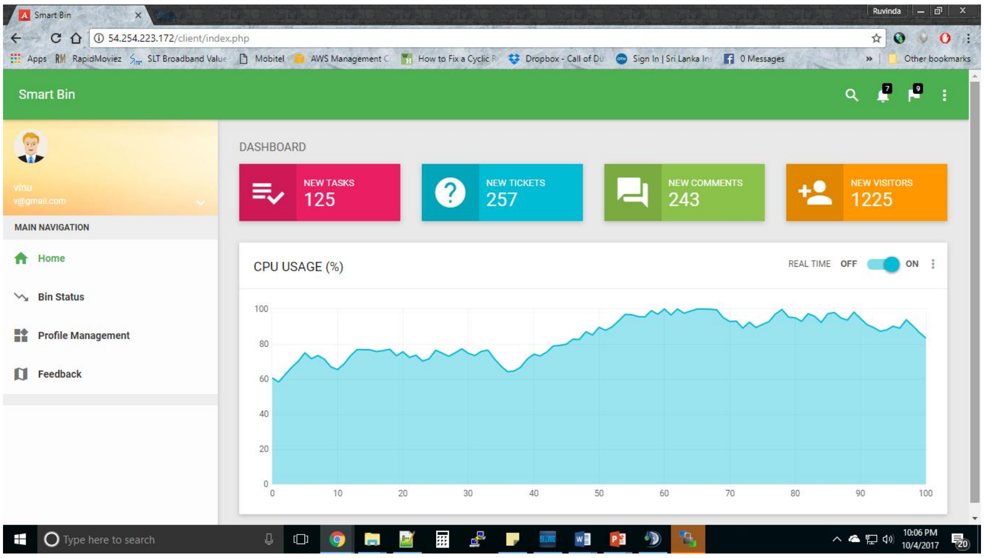

Figure 2.1.7.5.1: Client Dashboard

This is the home page of the client dashboard. The services provided by the system for the client can all be accessed here. The main functionalities are:

- Bin Status

  View bin status and locations of bins in a real-time map.

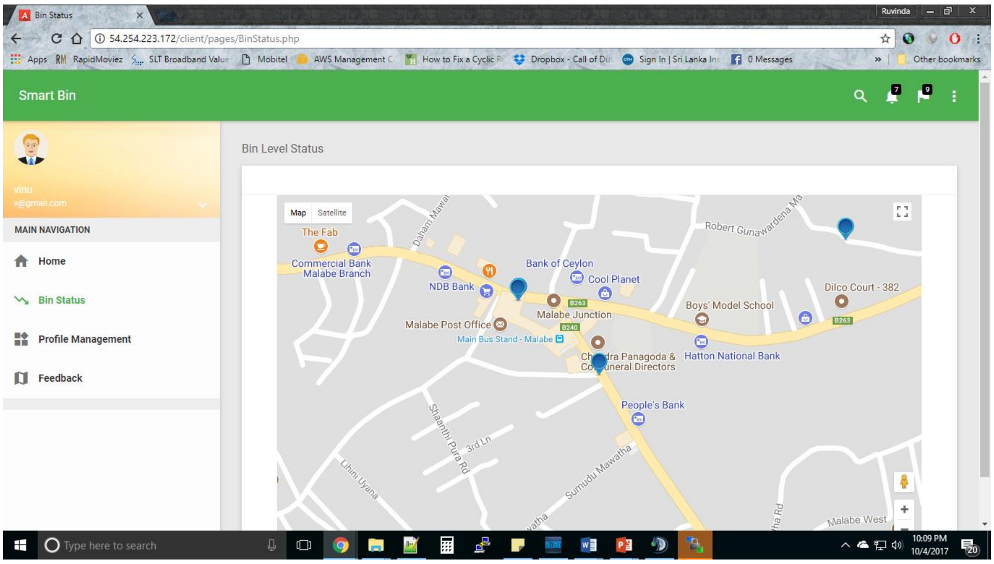

Figure 2.1.7.5.2: Bin Status Client

- Request Bins

  If bins on a certain location is constantly getting filled, or a certain place desperately needs new bins, users can specifically select the location and request a new bin on that location on the map.
- Edit User Profile

  Edit user profile settings like Name, Email, Password and Profile picture.
- Give Feedback

  There are 2 types of feedback which a client can use. They are
  - Bin maintenance request

    If a bin is not working or is not being cleaned properly, clients can lodge a special request to clean or replace the bin in question.
  - Other complains
- Get news and maintenance alerts

  Users get immediate alerts if there are new news alerts or maintenance alerts.

2.1.8 The Analysis of Municipal Solid Waste Generation

This analysis consists of two parts

- Predict amount of solid waste generated for periods of time for each region from each type of garbage.
- Make estimates of the profit to be gained by recycling the predicted municipal solid waste.

The first step to do both of these components is to record the weight of each type of garbage collected from each region. These are the steps used to record the values:

1. Each time a cleaner hit the deactivate bin button to clean a specific bin, the garbage level is uploaded to the server.
2. The level from each bin is converted to weight using the bin’s volume.
3. The amount of garbage collected of each type from each region is calculated from the stored amounts on a weekly basis.

4. The weekly values are used to predict the garbage levels in the coming months up to a year in the future.

Each month a report is created detailing the predictions made from the four weeks of the last month. This reported can be used by the government to implement techniques to reduce the use of materials like plastic. After a technique has been implemented, the new reports can be used to check how effective the technique is.

(This part is not complete, some calculations that should be added are not final yet)

2.1.9 End user application

Author will develop mobile application that can be operated minimum hardware requirement with more feature. To run end user android application will be needed minimum android KitKat 4.4.4 (API level 19) operating system or higher version. Therefore, run this application should be include following requirements in mobile device that are minimum 512 MB RAM (2GB recommended) and 1 GHz or higher processor. To connect Wi-Fi, mobile devices should support IEEE 802.11 b/g/n.

The workforce android application includes three main features.

1. Real time bin level and bin location visualizer

2. Feedback system

3. End user route calculation

Since this application is develop for users, author provide interface to registration. This will be the source that system will collect information about user. After registration user can access to function which it provides (Figure 2.1.9.1: Registration UI, Figure 2.1.9.2: Login UI)

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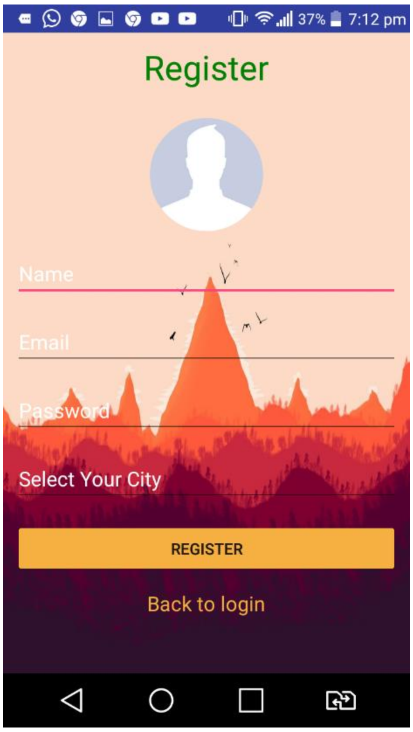


Figure 2.1.9.1: Registration UI

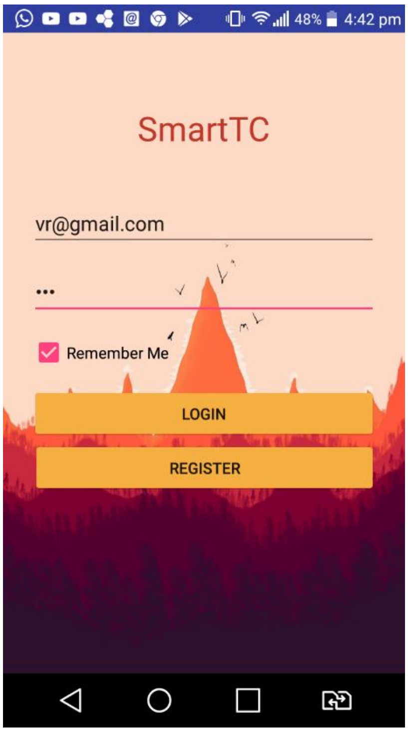


Figure 2.1.9.2: Login UI

2.1.9.1 Real time bin level and bin location visualizer

The map shows all the bins that are placed throughout the city. The user can access each bin to get all the specific information about the bin like real time level and other details. (Figure 2.1.9.1.1: Bin map, Figure 2.1.9.1.2: Bin detail)

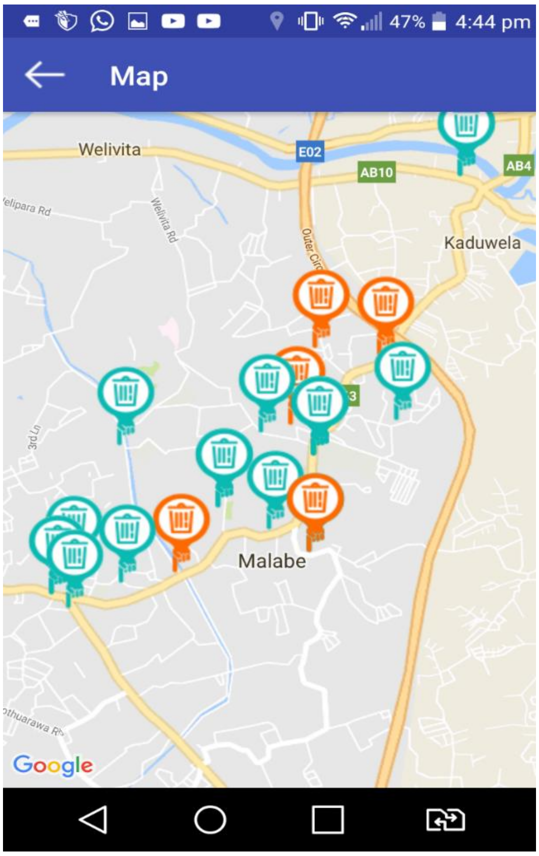
User can see location of all bins in the smart city through bin location map interface.

There are four type of garbage bins at one location.

1. Paper (PA)
2. Glass (GL)
3. Plastic (PL)
4. Biodegradable (BI)

Using all bin location interface, cleaner can see all type of bins each location, it's bin ID (Ex- MLB-10-BI) and current bin level status. The bin ID is created using area or zone number and putting garbage type. The current bin level status can be identified using google map location maker color. There are two types of makers.

1. Orange marker - Garbage filled level is 80% or high.
2. Green marker – Garbage filled level is less than 80%.



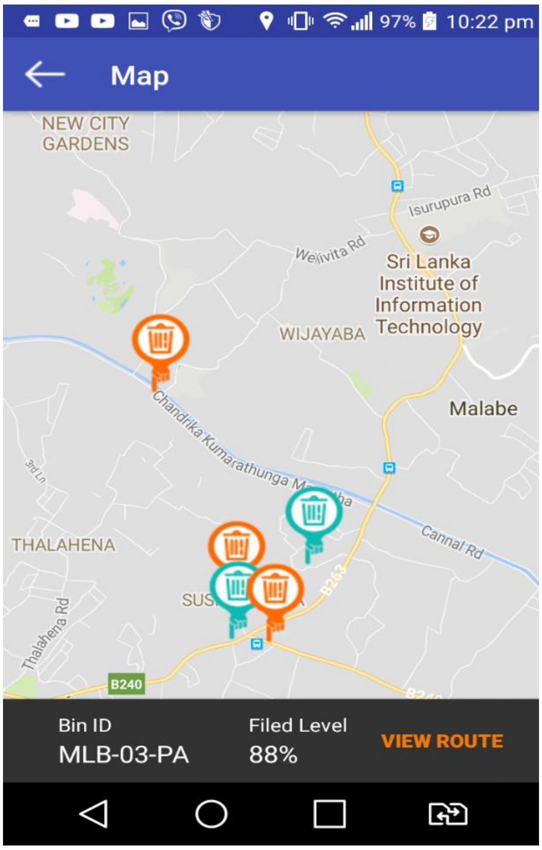


Figure 2.1.9.1.1: Bin map

Figure 2.1.9.1.2: Bin detail

2.1.9.2 Feedback system

In feedback system there is several types of feedbacks that user can send to our management.

- Bin maintains
- Bin request
- Cleaning issue
- other

When the bin is malfunctioning, user can let our system know that bin is not working properly by sending feedback. (Figure 2.1.9.2.1: Feedback SMS) When user send feedback using android application, this feedback will come to database and also it will notify the maintain staff by reserving SMS to their mobile number.

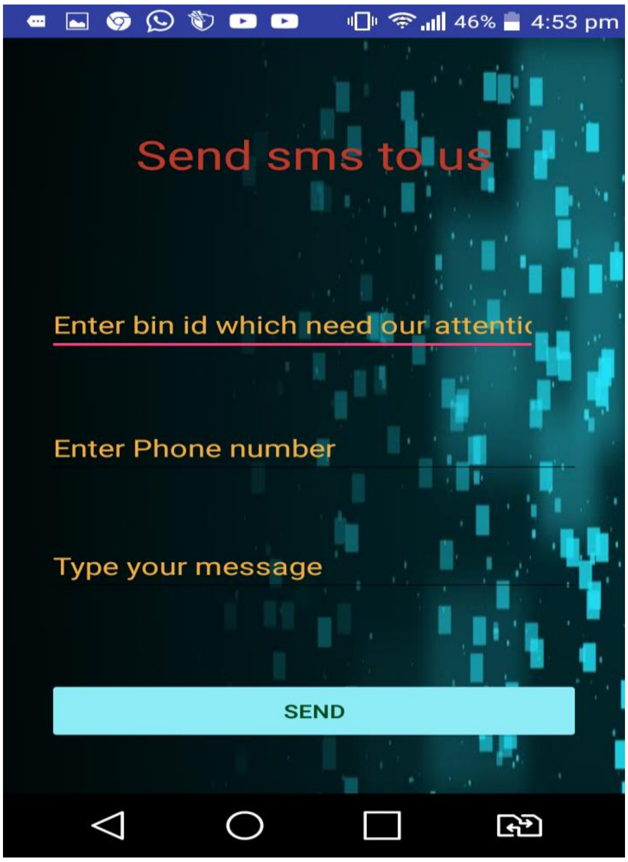


Figure 2.1.9.2.1: Feedback SMS

Author provide another UI for user to send other three types of feedbacks. (Figure 2.1.9.2.2: Feedback, Figure 2.1.9.2.3: Other Feedback)

User can select those feedback and send relevant feedback to our management. These feedbacks are collect in our database to do analytical calculation.

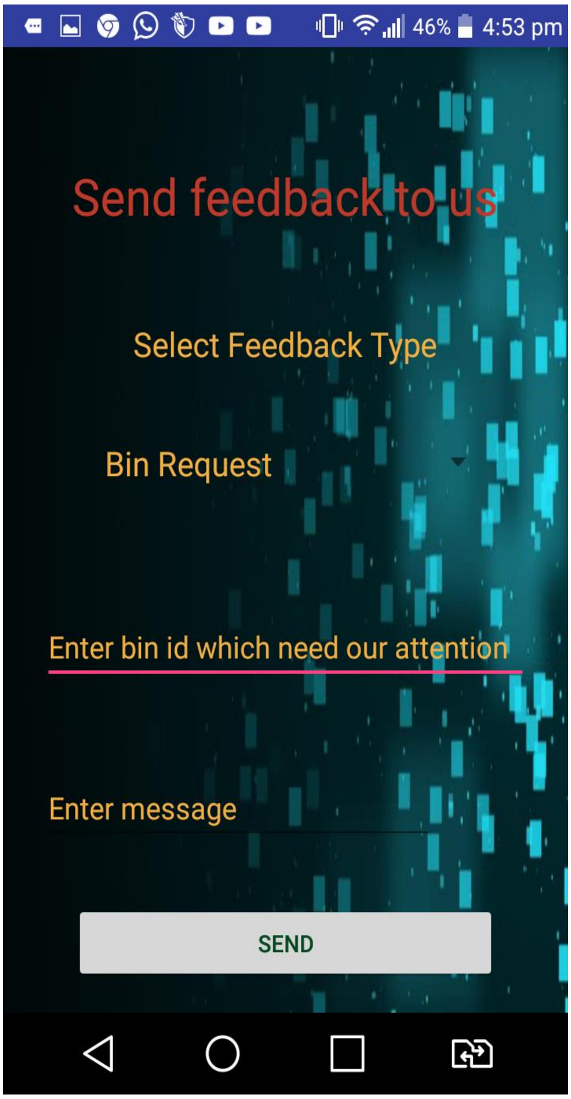


Figure 2.1.9.2.2: Feedback

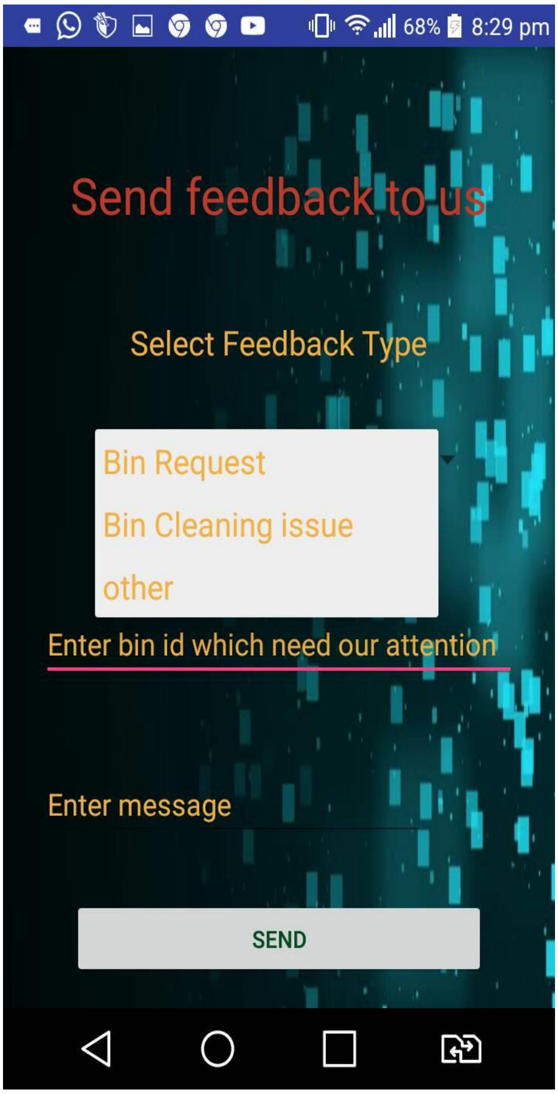


Figure 2.1.9.2.3: Other Feedback

2.1.9.3 End user route calculation

End user application provide the map which indicate all the bins. Also, this map will show the current location of the user. User can see all the bin which near to his current location.

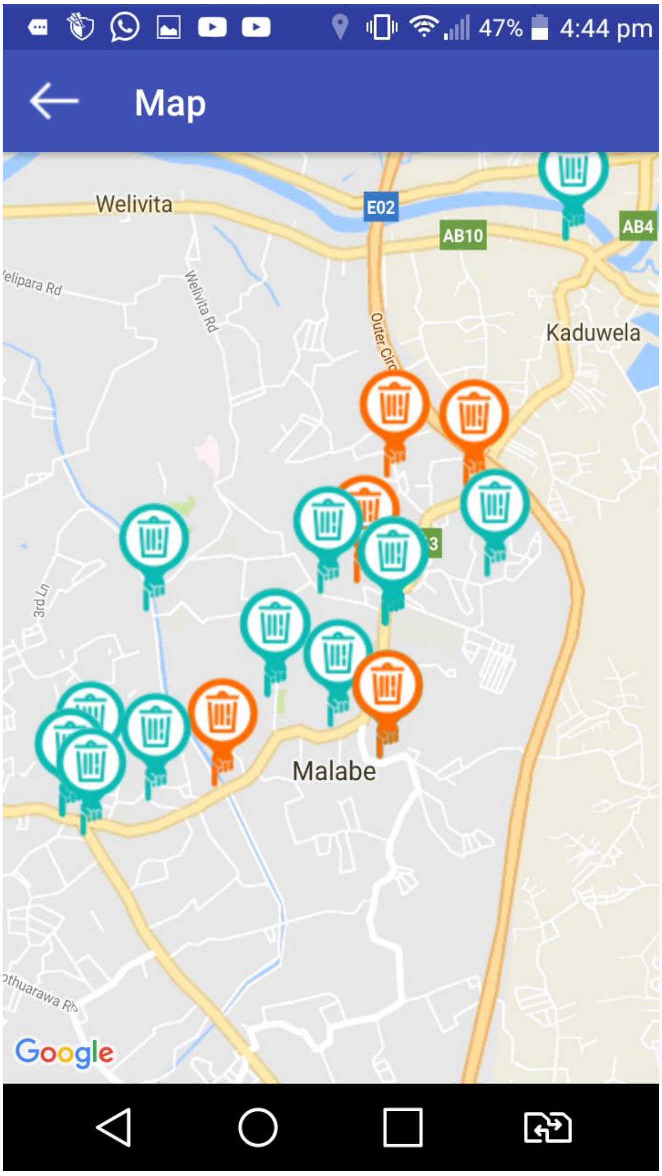


Figure 2.1.9.3.1: Current location with bins

Use can select the bin which has fill level less than 80% and view the all details about that bin. (Figure 2.1.9.3.2: Bin details). After user select bin, map provide view route to get the nearest route from user’s current location to selected bin. (Figure 2.1.9.3.3: Best route)

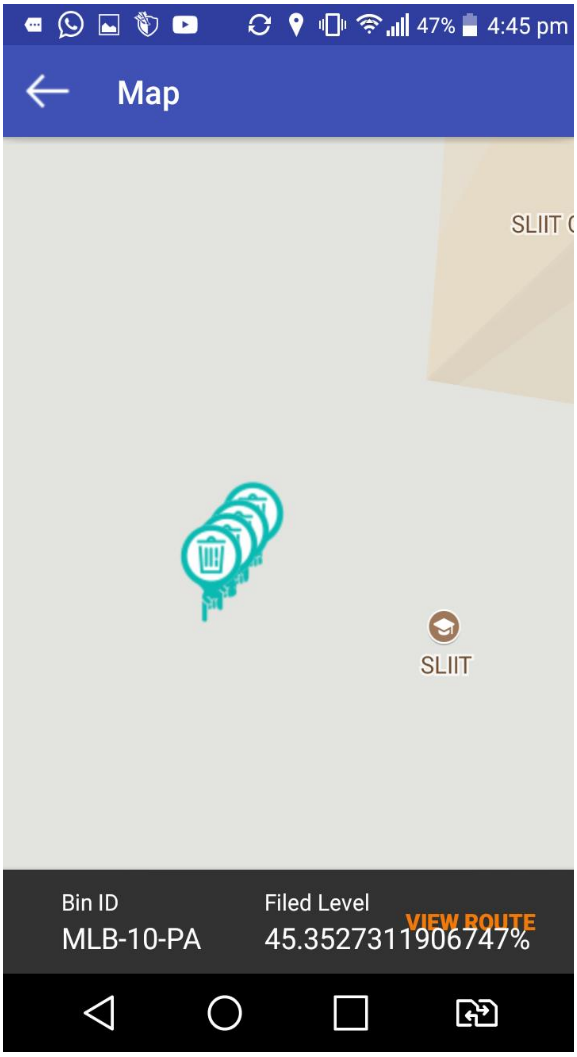


Figure 2.1.9.3.2: Bin details

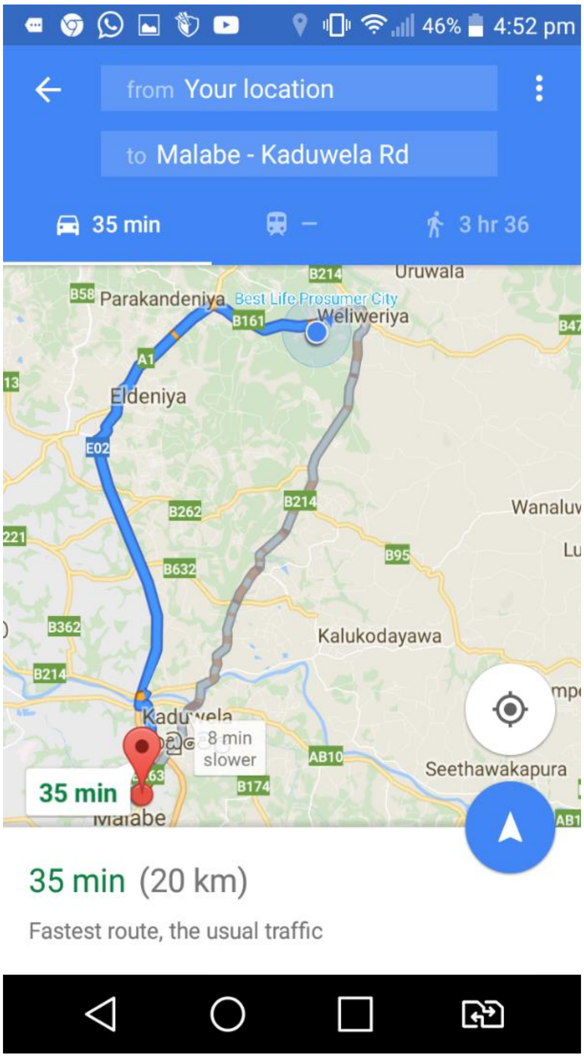


Figure 2.1.9.3.3: End user Best route

End user application overall diagram

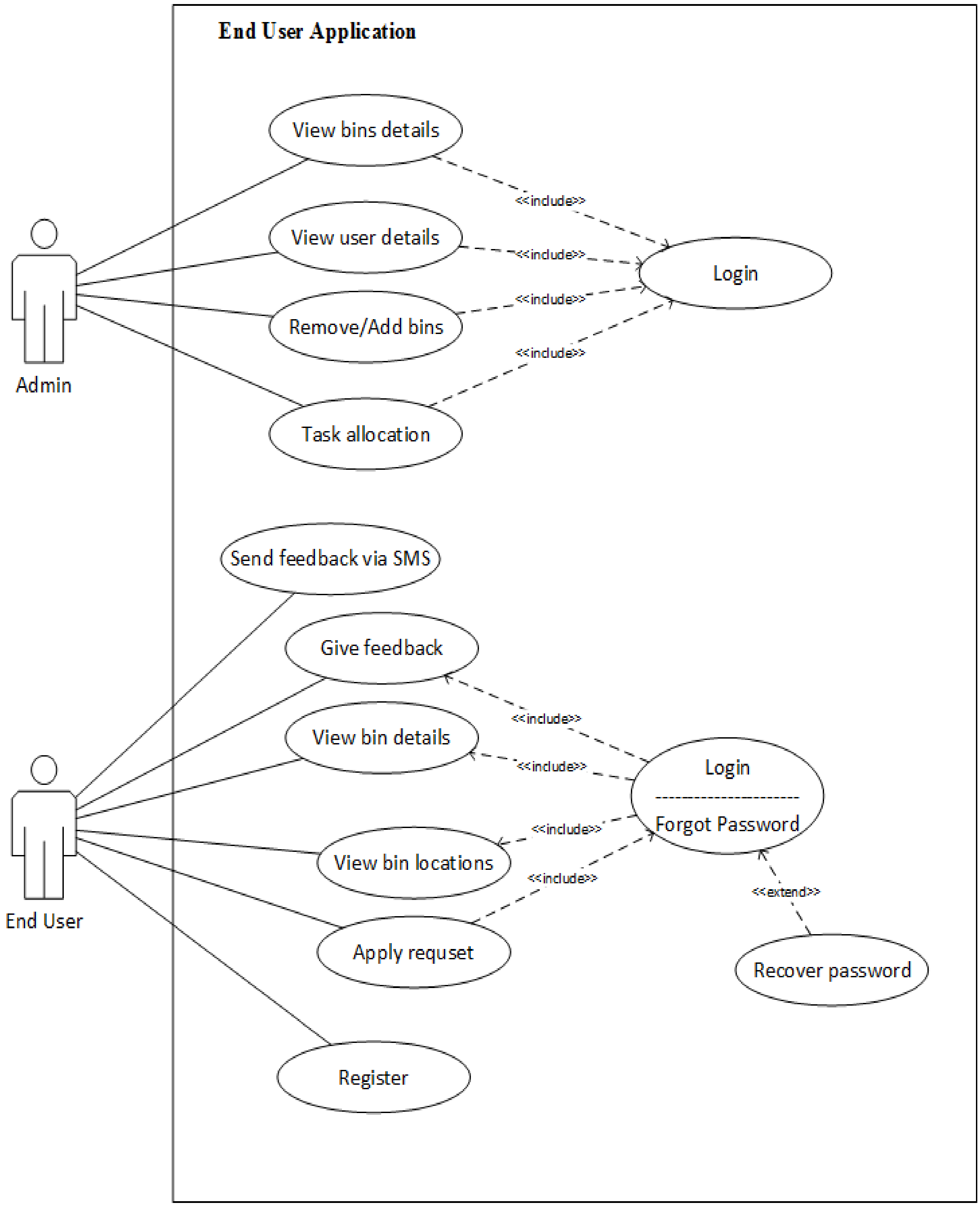


Figure 2.1.3.4: Use Case

2.1.10 Feedback Analytical system

In feedback analytical system author will mainly focus on the bin requesting feedbacks. Users can request bins in two ways. One is using android application. In here users can request bin which bins are already implemented but those bins are not enough for current usages. Another request method is requesting bin using web site. In here user can select position on map and request bin to that selected location. When the user selects some point on map author will get the nearest bins ids for that location. Those bin ids are send to database for analyzing. [13]

In analytical system author will analyze information which in database and provide efficient solution. Following flow chart will explain further. (Figure 2.1.10.1: analytical diagram)

There is another analytical part which is author will provide statically count the bins which need for ‘X’ number of populated city. In here author will get the one city which is currently successfully implemented our system. As example if we implement our system for kaduwela city by analyzing our data in database author can tell how many bins author uses for kaduwela city. According to this value author can generate value for bins which need for 100 people.

When the author going to implement system for new city, author can suggest how many bin needs for that city. For this author will get the previously calculated valued and current population of that city.

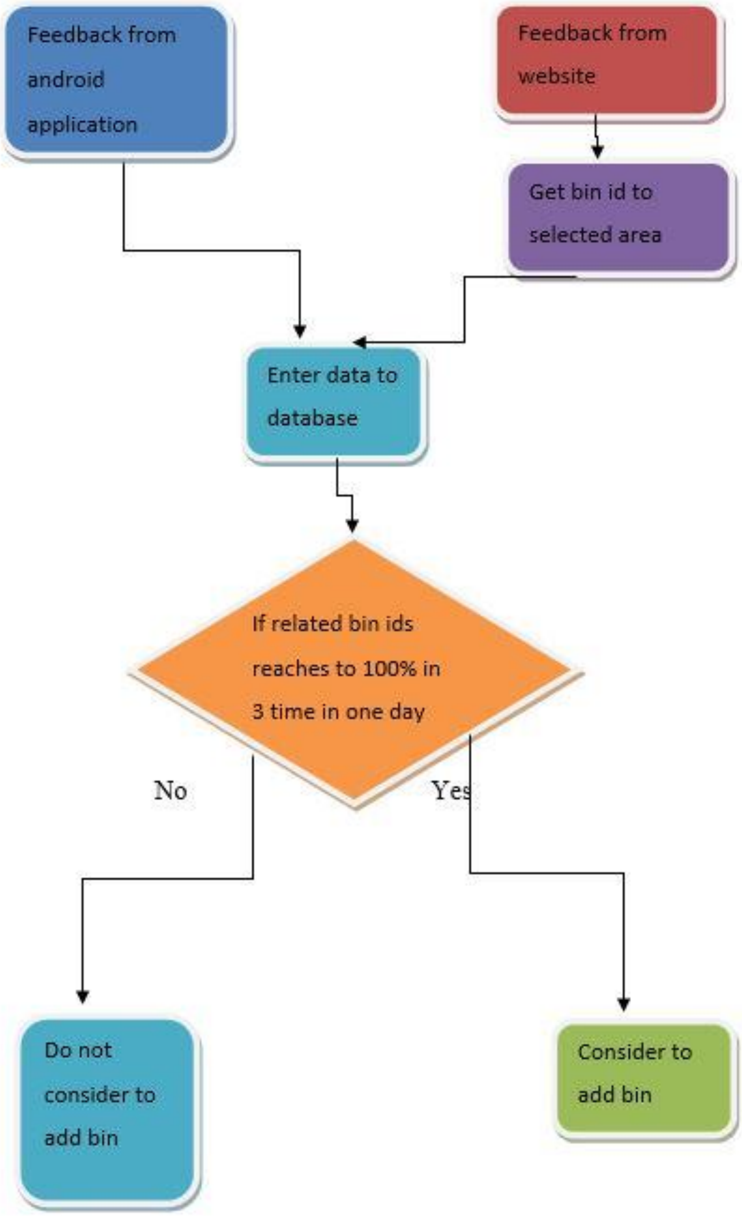


Figure 2.1.10: analytical diagram

2.1.11 Workforce user android application

Author will develop mobile application that can be operated minimum hardware requirement with more feature. To run workforce android application will be needed minimum android KitKat 4.4.4 (API level 19) operating system or higher version. Therefore, run this application should be include following requirements in mobile device that are minimum 512 MB RAM (2GB recommended) and 1 GHz or higher processor. To connect Wi-Fi, mobile devices should support IEEE 802.11 b/g/n.

The workforce android application includes three main features.

1. Real time bin level and bin location
2. Disabling/re-enabling the security system
3. Workforce user best route

2.1.11.1 Real time bin level and bin location

The map shows all the bins that are placed throughout the city. The cleaner can access each bin to get all the specific information about the bin like real time level and other details. Work force user can see location of all bins in the smart city through bin location map interface (Figure 2.1.11.2).

There are four type of garbage bins at one location. (Figure 2.1.11.1)

5. Paper (PA)
6. Glass (GL)
7. Plastic (PL)
8. Biodegradable (BI)

Using all bin location interface, cleaner can see all type of bins each location, it's bin ID (Ex- MLB-10-BI) and current bin level status. The bin ID is created using area or zone number and putting garbage type.

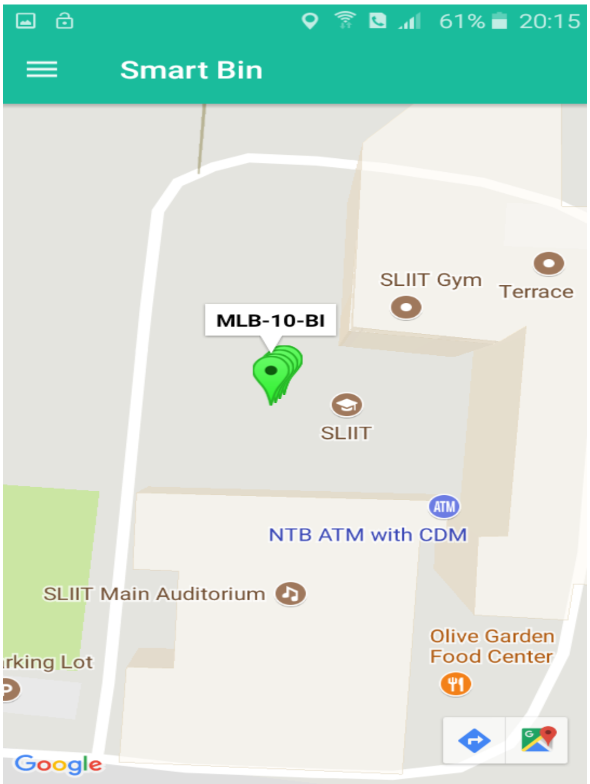


Figure 2.1.11.1: Four type of bin each place

The current bin level status can be identified using google map location maker colour. There are three types of makers.

3. Red marker - Garbage filled level is 100%
4. Orange marker - Garbage filled level is more than or equal 80%.
5. Green marker – Garbage filled level is less than 80%.

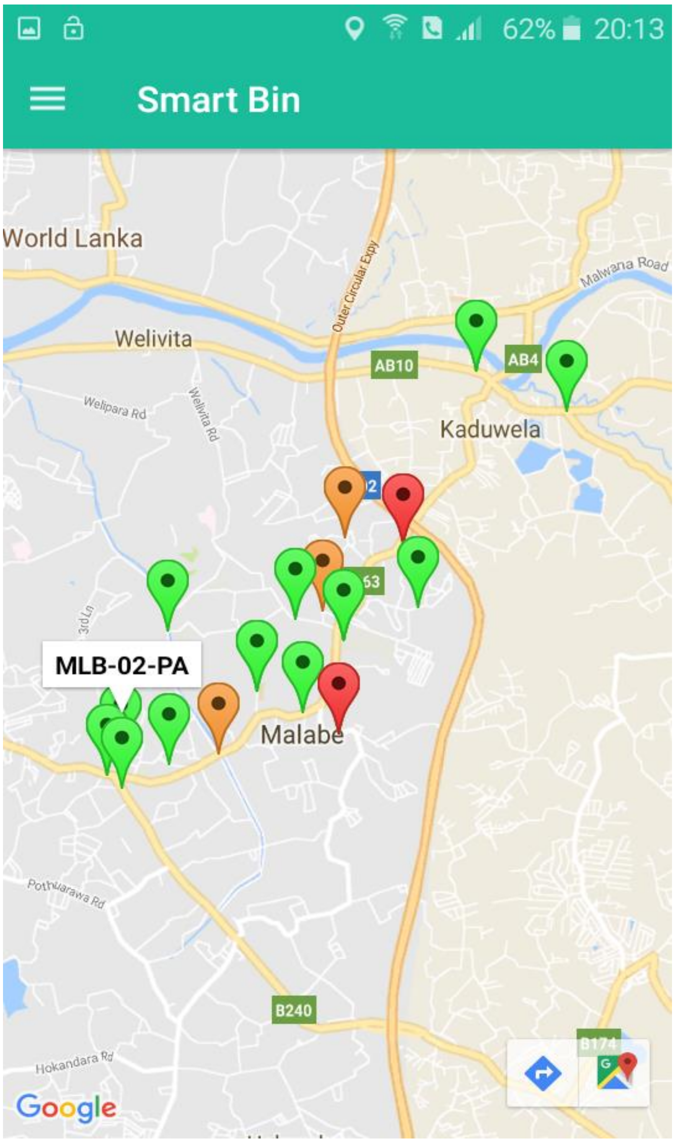


Figure 2.1.11.2: All bin location map

2.1.11.2 Disabling/re-enabling the security system

The bin has a security system that is enabled when its placed in the city. Using this feature cleaner can avoid unwanted data passing into the database. Because of while cleaner clan garbage bins it will happen move sensors and pass wrong data into database. When a cleaner has to clean a bin, the security system has to be disabling in order to do so. This function enables the cleaner to disable the security system at the start and re- enable it when the cleaning is finished.

Using Bin details interface (Figure 2.1.11.2.1), work force user should enter bin ID in search bar. After that app will be loaded information and user can enabling and disabling security system using switch which is relevant bin.

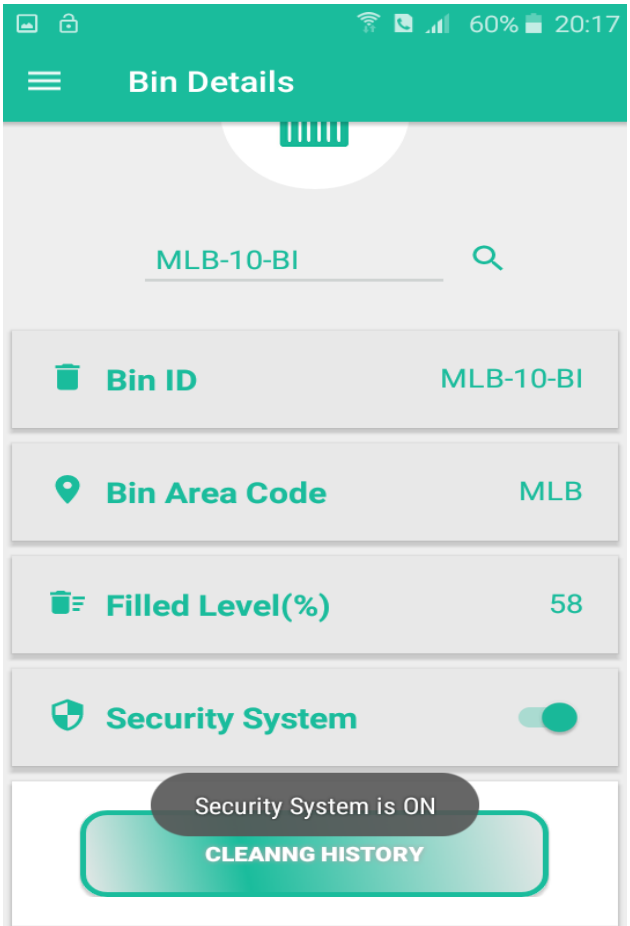


Figure 2.1.11.2.1: Bin details

2.1.11.3 Best route

The figure 2.1.11.3.1 indicates a normal map of a city. Bins have been placed on usual locations. The available bins are colored green, bins that are going to be over an 80% in orange, bins that are completely filled in red.

The priority for calculating the route is given to the orange bin and the red bins. When a bin reaches 80% capacity the system checks which of the nearest bins are going to be filled in the future on a given period of time. These bins are marked in yellow based on route calculation algorithm.

An algorithm is developed for each bin which describes how the bins are going to be filled. Our database is constantly updated by new capacity values. This data is taken as the past data to predict future fill levels.

After predicting the bins using the above algorithm, the identified bins are marked as waypoint on the route that is being calculated. Then use google maps to calculate the route using the base station, 80% filled bin and the waypoints. Google maps use Dijkstra's algorithm to calculate the shortest path (Figure 2.1.11.3.2).

The author uses GPS or network based tracking system to provide current location and provide best route. In figure 2.1.11.3.2 green colour marker indicate current location of cleaner and red colour marker indicate end point which is disposal point for collected garbage.

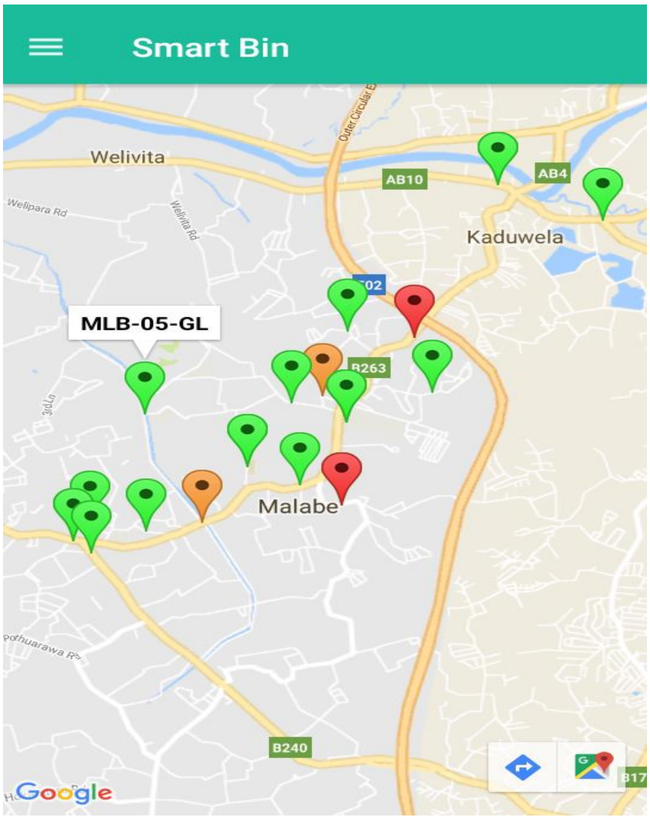


Figure 2.1.11.3.1: All bin location

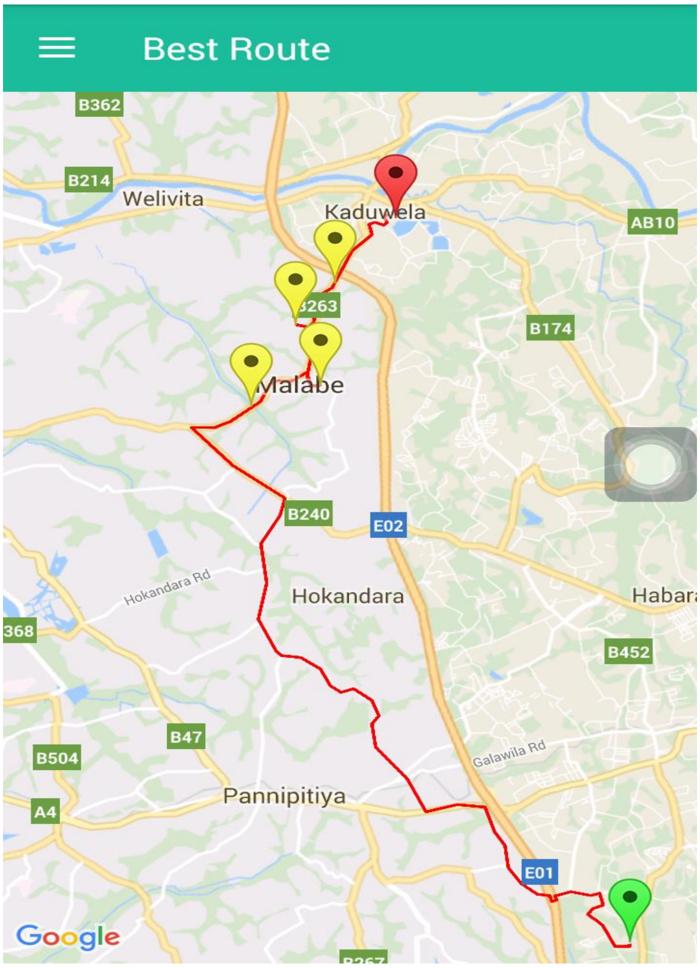


Figure 2.1.11.3.2: Best route map

2.1.11.4 Workforce application other features

Cleaning History

There is a button in the bin details interface (Figure 2.1.11.2.1) known as "Cleaning History". Using that button, cleaner can see details about cleaning history that was entered bin ID in search bar. Through cleaning history interface (Figure 2.1.11.4.1) provide cleaner name, date and time which has been sorted descending order of date and time.

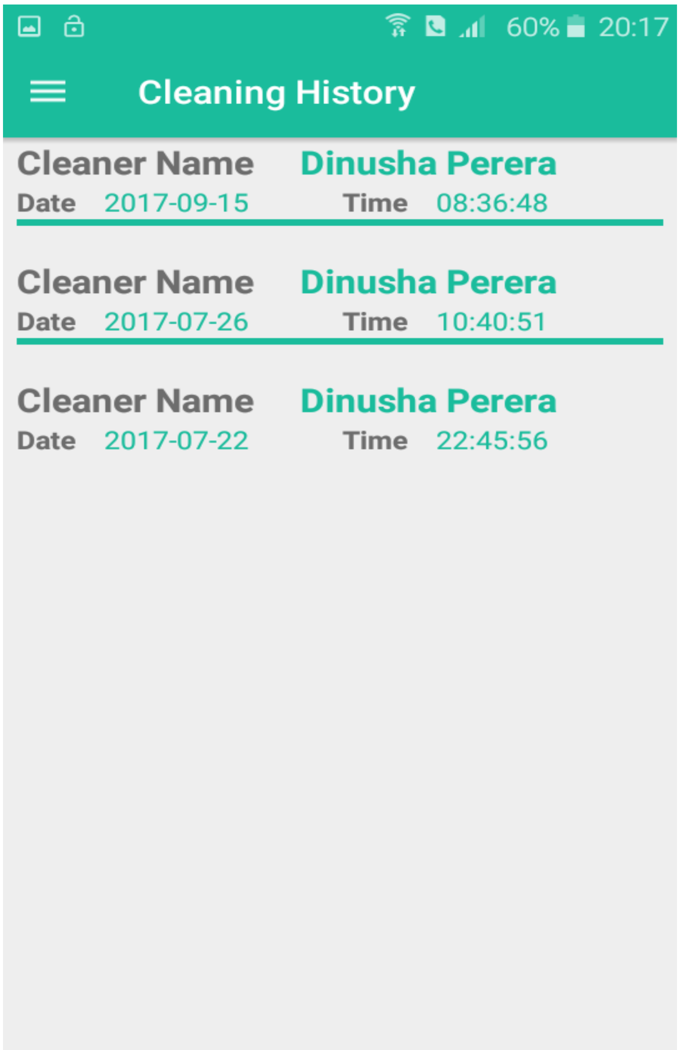


Figure 2.1.11.4.1: Cleaning history

Working history

The cleaners can see their cleaning history through clicking navigation drawer (Figure 2.1.11.4.2) working history item. The working history interface (Figure 2.1.11.4.3) provide bin ID, Area name, date and time.

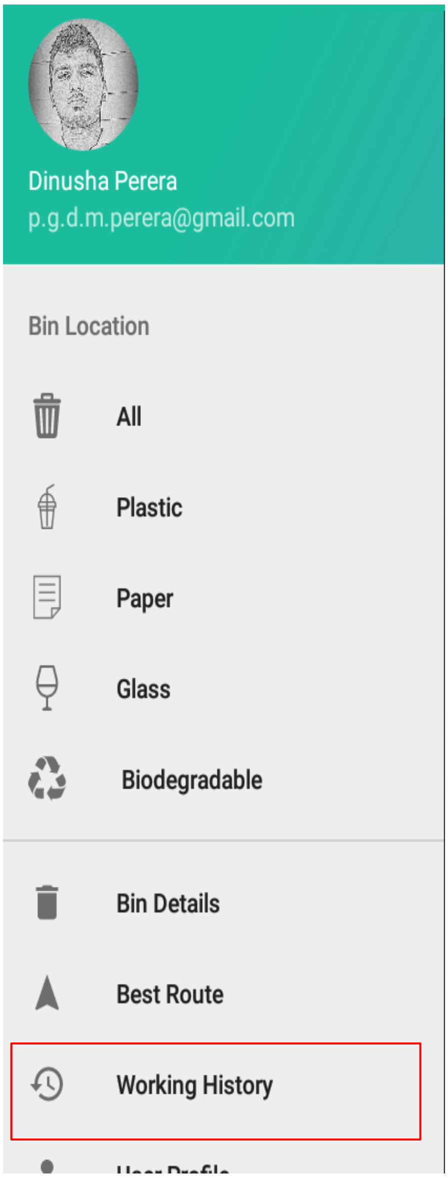


Figure 2.1.11.4.2: Navigation drawer

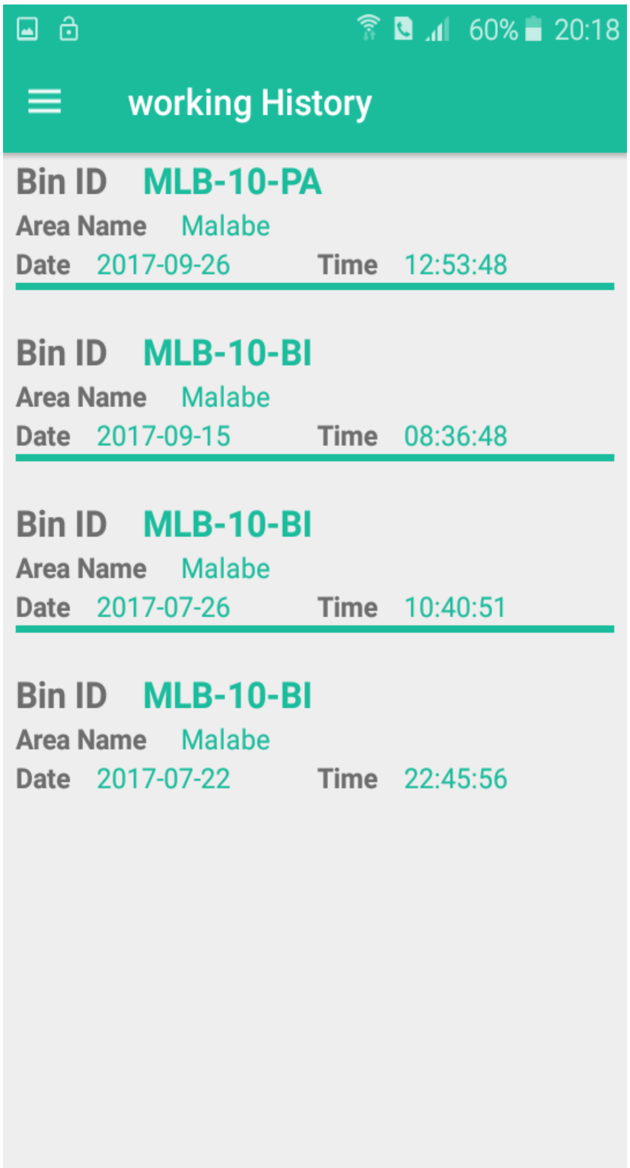


Figure 2.1.11.4.3: Working history

2.1.12 Workforce user route calculation algorithm

In route calculation, the cleaning trucks go to clean garbage bins in smart city three time per day. That time are 6.00 a.m., 12.00 p.m. and 6.00 p.m. In that each time two things are checked to add as a waypoint each bin in the zone.

- When cleaning trucks go to clean at 6.00 a.m.

  Route calculation find what are the bins recently over 80% filled level and what will the bins be over 80% filled level at 9.30 a.m. using last five weeks predicted data. Route calculation algorithm will add each bin which is one of these conditions are satisfied as a waypoint.

- When cleaning trucks go to clean at 12.00 p.m.

  Route calculation find what are the bins recently over 80% filled level and what will the bins be over 80% filled level at 15.30 p.m. using last five weeks predicted data. Route calculation algorithm will add each bin which is one of these conditions are satisfied as a waypoint.

- When cleaning trucks go to clean at 6.00 p.m.

  Route calculation find what are the bins recently over 80% filled level and what will the bins be over 80% filled level at 09.30 p.m. using last five weeks predicted data. Route calculation algorithm will add each bin which is one of these conditions are satisfied as a waypoint.

As an example, let see how to add a bin on Monday at 6.00 a.m. as a waypoint in best route though the flow chat (Figure 2.1.12.1).

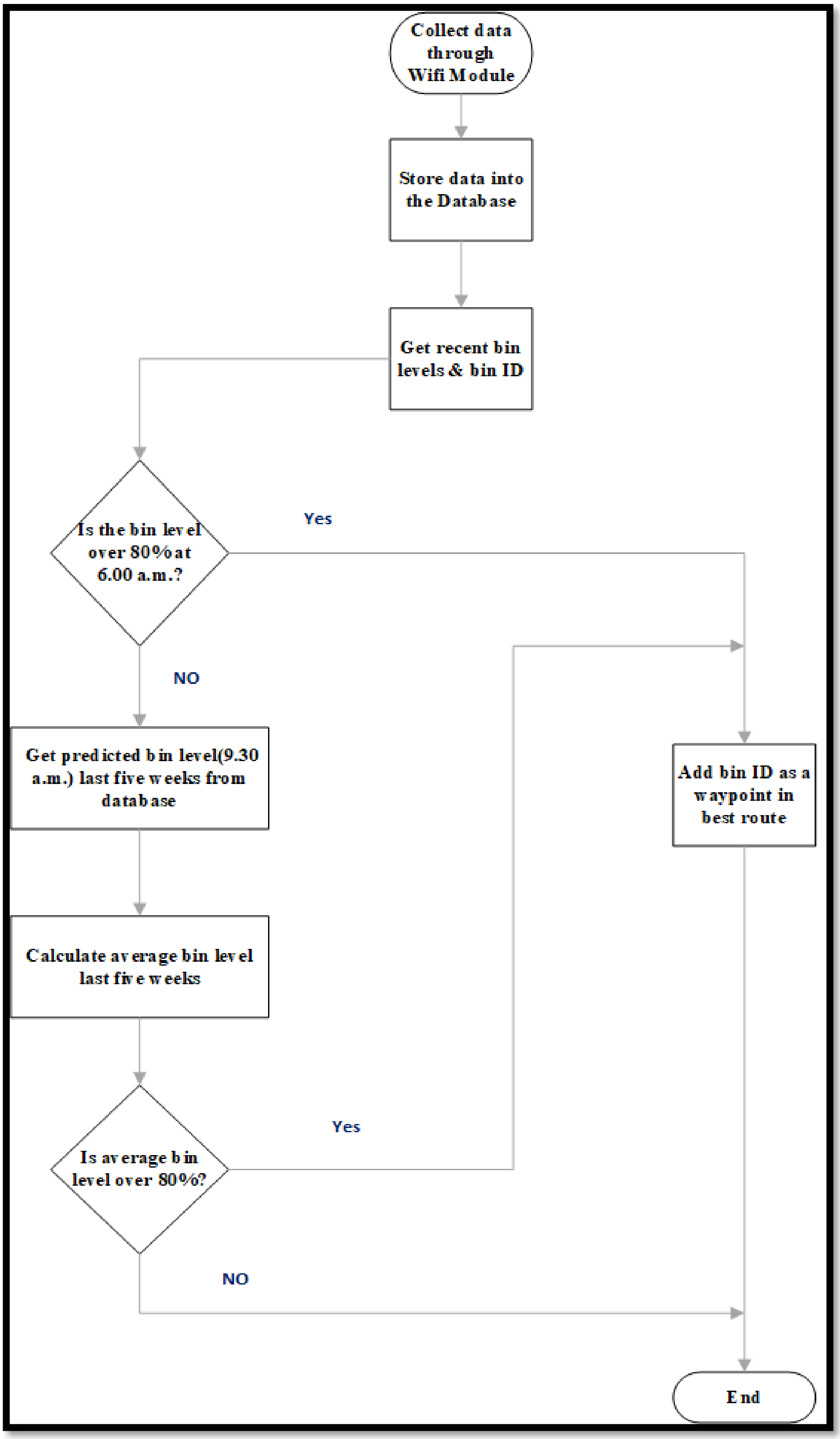


Figure 2.1.12.1: Add a bin as a waypoint – Flowchart

To predict future bin level, route calculation algorithm use interpolation. Interpolation is the process of finding the values of y corresponding to the any value of x between x_0 and x_n for the given values of y = f(x) for a set of values of x.

Interpolation equation:

$$\mathbf{f(x) = f_0 + r\Delta f_0 + \frac{r(r-1)}{2!}\Delta^2 f_0 + \frac{r(r-1)(r-2)}{3!}\Delta^3 f_0 + \frac{r(r-1)(r-2)(r-3)}{4!}\Delta^4 f_0}$$

$$\mathbf{+ \frac{r(r-1)(r-2)(r-3)(r-4)}{5!}\Delta^5 f_0 + \frac{r(r-1)(r-2)(r-3)(r-4)(r-5)}{6!}\Delta^6 f_0}$$

Now let see how to predict bin level on Monday at 9.30 a.m.

Table 2.1.12.1: collected data hourly from 6.00 a.m. to 12.00 p.m.

x	6	7	8	9	10	11	12
f(x)	28	35	41	45	53	61	69

Method 1 - Predict bin level using interpolation equation.

Table 2.1.12.2: Calculation Table (Method 1)

x	**f(x)**	**Δf**	**Δ^2f**	**Δ^3f**	**Δ^4f**	**Δ^5f**	**Δ^6f**
6	**28**						
7	35	**7**					
8	41	6	**-1**				
9	45	4	-2	**-1**			

10	53	8	4	6	**7**		
11	61	8	0	-4	-10	**-17**	
12	69	8	0	0	4	14	**31**

$$\mathbf{f(x) = f_0 + r\Delta f_0 + \frac{r(r-1)}{2!}\Delta^2 f_0 + \frac{r(r-1)(r-2)}{3!}\Delta^3 f_0 + \frac{r(r-1)(r-2)(r-3)}{4!}\Delta^4 f_0}$$

$$\mathbf{+\frac{r(r-1)(r-2)(r-3)(r-4)}{5!}\Delta^5 f_0 + \frac{r(r-1)(r-2)(r-3)(r-4)(r-5)}{6!}\Delta^6 f_0}$$

$h = x_1 - x_2 = 7 – 6 = 1$

$r = (x – x_0)/h = (9.5-6)/1$

$=3.5$

$$f(9.5) = 28 + (3.5)(7) + \frac{(3.5)(2.5)}{2!}(-1) + \frac{(3.5)(2.5)(1.5)}{3!}(-1) + \frac{(3.5)(2.5)(1.5)(0.5)}{4!}(7)$$

$$+\frac{(3.5)(2.5)(1.5)(0.5)(-0.5)}{5!}(-17) + \frac{(3.5)(2.5)(1.5)(0.5)(-0.5)(-1.5)}{6!}(31)$$

$f(9.5)=28+24.5-4.375-2.1875+1.9140+0.4648+0.2119+0.4238$

$= 48.5283$

Answer = 48.5283

Method 2 - Predict bin level using java program.

```
public void alogrithm()
    {
        float x[]=new float[20];
        float y[]=new float[20];
        float f,s,h,d,p;
        int j,i,n;

        n=7;
        x[1]=6.0f;
        x[2]=7.0f;
        x[3]=8.0f;
        x[4]=9.0f;
        x[5]=10.0f;
        x[6]=11.0f;
        x[7]=12.0f;

        y[1]= 28.0f;
        y[2]= 35.0f;
        y[3]= 41.0f;
        y[4]= 45.0f;
        y[5]= 53.0f;
        y[6]= 61.0f;
        y[7]= 69.0f;

        f=9.50f;
        h=x[2]-x[1];
                s=(f-x[1])/h;
                p=1.0f;
                d=y[1];

                for(i=1;i<=(n-1);i++)
                {
                   for(j=1;j<=(n-i);j++)
                    {
                           y[j]=y[j+1]-y[j];

                    }
                    p=p*(s-i+1)/i;
                    d=d+p*y[1];
                }

System.out.println(String.format("%6.1f,%6.2f",f,d));
    }
}
```

Figure 2.1.12.2: Bin level prediction algorithm

```
root@ip-172-31-22-84:/usr/smartbin# vi alogrithm.java
root@ip-172-31-22-84:/usr/smartbin# javac alogrithm.java
root@ip-172-31-22-84:/usr/smartbin# java alogrithm
   9.5, 48.53
root@ip-172-31-22-84:/usr/smartbin#
```

Figure 2.1.12.3: Bin level prediction algorithm output

Bin level is 48.53% at 9.30 a.m.

Likewise, algorithm predict five weeks bin level and those data will be store in MySQL database. Those data will be added to route calculation algorithm and calculate best route for working staff.

2.2 Testing and Implementation

Each and every sub components in smart trash can system is tested before the integration into a one program. Garbage level measure system, Hand gesture system and Safety system are tested individually and then integrated as a one program to run independently. Uploaded garbage level can be checked within the MySQL database and compared to the calculated garbage level by giving a simple print command.

The Webserver and the Website was tested through each function according to the expected output, and tested to ensure that the system was error free. User acceptance testing was done by two users. Since performance is a high priority concern area in a webserver, all the components were integrated and tested. The two applications, the bin and the website was run simultaneously to see if the load was too high for the server. The server seemed to work fine under high number of requests from each component.

The Workforce android application was tested through each function according to the expected output, and tested to ensure that the system was error free. User acceptance testing was done by two users. Since performance is a high priority concerned area in a networked application.

A performance test is conducted under the network connectivity of both WIFI network bandwidth (802.11 standards) and under mobile network bandwidth HSPA (H). The conducted test yield, following the results for each method exposed in the web API under mobile network bandwidth connectivity speed of HSPA and WIFI connectivity.

2.2.1 Assumptions

One of the main assumption is smart city is consisted with Wi-Fi and solar power. Without being connected to a Wi-Fi network trash can can't upload the calculated garbage level to the server. Trash can needs a 5v power input via the power grid or the solar panels in the smart city.

Another assumption is user should use their hand gesture system to open and close the bin. At least need a one single motion to open the bin lid and if user forget close the lid with another hand gesture bin will automatically close its lid.

One assumption about the product is that the GPS components in all Android smartphones work in the similar manner. Another assumption about the product is that it will always be used on mobile phones that have enough performance. The smart phones should enable GPS. Another main assumption is database server up and running 100%. The application is operating system dependent and should be running only on Android (Minimum Android 4.4.4 KitKat) powered Smart Phones.

2.2.2 Test Case – Smart Bin

Table 2.2.2.1: Test case 01

Test ID	01
Description	User should be able to open the trash can's lid
Pre-condition	Trash can should be powered on and connected to a wifi network.
Actors	Citizens, Workforce staff
Main Flow Events	1. Get near to the smartbin 2. Perform a simple hand gesture.
Expected Output	Bin lid will open after the hand gesture
Actual Output	As expected bin lid is opened

Table 2.2.2.2: Test case 02

Test ID	02
Description	User should be able to close the trash can's lid
Pre-condition	Trash can lid should be opened.
Actors	Citizens, Workforce staff
Main Flow Events	1. Get near to the smart bin 2. Perform a simple hand gesture.
Expected Output	Bin lid will close after the hand gesture
Actual Output	As expected bin lid is closed

Table 2.2.2.3: Test case 03

Test ID	03
Description	User forget to close the trash can's lid
Pre-condition	Trash can lid should be opened. bin lid's opened time should be exceeded 30seconds
Actors	System
Main Flow Events	1. Check whether the bin lid is open 2. Execute the closing lid function
Expected Output	Bin lid will be automatically closed.
Actual Output	As expected bin lid is closed

Table 2.2.2.4: Test case 04

Test ID	04
Description	Garbage level measuring
Pre-condition	Execute after the trash can lid closed.
Actors	System
Main Flow Events	1. Get the ultrasonic sensors readings 2. Calculate the garbage filed level
Expected Output	Calculating the average garbage filed level
Actual Output	As expected calculated the average garbage filed level

Table 2.2.2.5: Test case 05

Test ID	05
Description	Garbage level uploading to server
Pre-condition	Garbage level should be calculated.
Actors	System
Main Flow Events	1. Establish the database connection with the server 2. Update the filed level of the specific garbage bin
Expected Output	Garbage level will be update in the database.
Actual Output	As expected garbage level will be update in the database.

Table 2.2.2.6: Test case 06

Test ID	06
Description	Disable sensors via workforce application.
Pre-condition	Established database connection
Actors	System
Main Flow Events	1. From workforce application switch the toggle button to enable the safety measures 2. Smart bin identified the bin set into inactive state 3. Execute the sensor disabling function
Expected Output	Trash can’s sensors will be disable.
Actual Output	As expected trash can’s sensors are disabled.

2.2.3 Test case – Web site

Table 2.2.3.1: Test case 01

Test ID	01
Description	User should be able to login into the system.
Pre-condition	User must load up the website
Actors	Admin/Client
Main Flow Events	1. Load the website 2. Click on 'Dashboard' 3. Enter credentials 4. Click login
Input	Correct username and password.
Expected Output	Respective admin or client dashboard loads up
Actual Output	Respective admin or client dashboard loads up successfully

Table 2.2.3.2: Test case 02

Test ID	02
Description	User should be able to monitor all available bin locations and levels.
Pre-condition	User must be logged in to the system
Actors	Admin/Client
Main Flow Events	1.login to system 2. Click view bin detail map
Expected Output	A map with markers loads up.
Actual Output	A map with markers loads up successfully.

Table 2.2.3.3: Test case 03

Test ID	03
Description	Admin should be able to receive different types of progress/review reports
Pre-condition	Admin must be logged in to the system
Actors	Administrator
Main Flow Events	1. login to system 2. Click reports button
Expected Output	The reports page loads up.
Actual Output	The reports page loads up successfully.

Table 2.2.3.4: Test case 04

Test ID	04
Description	Admin should be able to add new bins to required location of the map
Pre-condition	Admin must be logged in to the system
Actors	Administrator
Main Flow Events	1. login to system 2. Click on the monitoring system map to check required locations 3. Add bins from the map
Expected Output	Add bins map loads up.
Actual Output	Add bins map loads up successfully.

Table 2.2.3.5: Test case 05

Test ID	05
Description	Admin should be able to view all the feedback the clients have given regarding the system
Pre-condition	Admin must be logged in to the system.
Actors	Administrator
Main Flow Events	1. login to system 2. Click feedback button
Expected Output	Feedback management page loads up.
Actual Output	Feedback management page loads up successfully.

Table 2.2.3.6: Test case 06

Test ID	06
Description	User should be able to give feedback to the system
Pre-condition	User must be logged in to the system
Actors	Client
Main Flow Events	1. login to system 2. Click on feedback
Expected Output	Feedback page loads up successfully.
Actual Output	Feedback page loads up successfully.

Table 2.2.3.7: Test case 07

Test ID	07
Description	User should be able to request new bins on specific locations
Pre-condition	User must be logged in to the system
Actors	Client
Main Flow Events	1. login to system 2. Click on request bins
Expected Output	A map with to request bins loads up.
Actual Output	A map with request bins up successfully.

2.2.4 Test case – Workforce android application

Table 2.2.4.1: Test case 01

Test ID	01
Description	User should be able to login into the system.
Pre-condition	Application must install in user's smart phone and connect to internet
Actors	Admin, Cleaner
Main Flow Events	1. Open application 2. Fill the text box. 3.Click Login button.
Input	Correct username and password.
Expected Output	The message which is "Welcome" display and move to the main activity.
Actual Output	The message which is "Welcome" display and move to the main activity.

Table 2.2.4.2: Test case 02

Test ID	02
Description	User should be able to view all available bins within his area and bin details.
Pre-condition	Connect to Wi-Fi or mobile network. Login to android application and enable GPS
Actors	Cleaner
Main Flow Events	1.login to system 2. Click markers.
Expected Output	Show bin ID when clicking marker.
Actual Output	Show bin ID when clicking marker.

Table 2.2.4.3: Test case 03

Test ID	03
Description	User can see suitable path for collect garbage
Pre-condition	Connect to Wi-Fi or mobile network. Login to android application and enable GPS
Actors	Cleaner
Main Flow Events	1. Login to android application 2. Click “Best route” item in navigation drawer
Expected Output	Show the best route with waypoint.
Actual Output	Show the best route with waypoint.

Table 2.2.4.4: Test case 04

Test ID	04
Description	Disabling/Enabling security system
Pre-condition	Connect to Wi-Fi or mobile network. Login to android application.
Actors	Cleaner
Main Flow Events	4. Login to android application 5. Go to the bin details interface 6. Search needed bin 7. Click change status switch
Expected Output	Security system enable or disable
Actual Output	Security system enable or disable

Table 2.2.4.5: Test case 05

Test ID	05
Description	Display cleaning history relevant bin with cleaner's name and time.
Pre-condition	Connect to Wi-Fi or mobile network. Login to android application.
Actors	Cleaner
Main Flow Events	1. Login to android application 2. Go to the bin details interface 3. Search needed bin 4. Click cleaning history button
Expected Output	Display cleaning history
Actual Output	Display cleaning history

Table 2.2.4.6: Test case 06

Test ID	06
Description	Display working history logged user with bin ID and time.
Pre-condition	Connect to Wi-Fi or mobile network. Login to android application.
Actors	Cleaner
Main Flow Events	1. Login to android application 2. Go to Navigation drawer 3. Click “working history” item
Expected Output	Display working history
Actual Output	Display working history

2.2.5 Test case - End user android application

Table 2.2.5.1: Test case 01

Test case 01	End user registration
Description	User should be able to Register to system
Pre-condition	End user application must install in user’s smart phone
Primary user	Citizen
Main flow of events	1. Open application 2. Fill the form by providing details

Table 2.2.5.2: Test case 02

Test case 02	View map detail/ view bin location
Description	User should be able to view all available bins within his area and bin location
Pre-condition	Users must be login to system
Primary user	citizen
Main flow of events	1. login to system 2. Request available bin within area by clicking view map detail button

Table 2.2.5.3: Test case 03

Test case 03	Give feedback
Description	Give feedback about custom service and vulnerabilities of system
Pre-condition	Login to android application or web site
Primary user	Citizen
Main flow of events	1. login to android application or website 2. go to feedback section 3. write feedback

2.3 Research Findings

At the very early stages of the research, something that was noted was that there were some studies conducted in the field of the ‘Location Based Garbage Management System with IOT for Smart City’. There were research papers even related to the individual research components of the group members. But the main notable point was that this research was unique, in the sense that there were no researches which integrated all of the research components that was integrated into this system. So more in-depth research studies were conducted, some professors were consulted and based on some good research components from different studies, the research components of this project were finalized.

Then it was time for the components. Initially an Arduino board was selected as the development board, but then switched to Raspberry Pie Zero due to the lack of parallel processing in the Arduino board.

An Infrared sensor was considered to measure distance, but some incompatibilities arose due to the fact that the Raspberry Pie Zero board did not contain any analog pins, and the Infrared sensor operated on analog signals. An analog signal contains infinite number of levels, the digital signal contains only two levels, so when an analog to digital converter was used a base voltage has to be given; the IR signal is checked against this base voltage to see if the signal is higher or lower. The problem arises when different types of garbage is used, the base value has to be changed when the garbage type changes. This cannot be done. So, the switch to an ultrasonic sensor was made, since they were digital. A Waterproof ultrasonic sensor was selected, since the bins had to be kept in the open.

3.0 RESULTS AND DISCUSSION

The research produced a usable, functional product that allows citizens to dump their trash, and without a human expert measures the filled garbage value as well as check for sensor errors. The outputs and outcomes of this research is discussed in this section as well.

In figure 3.0.1 illustrates the components for the hand gesture system. Marked ultrasonic sensor is used to open and close the lid. Servo motor will perform a 90° degree rotation for open and close the lid.

Figure 3.0.1: Motion sensor & Servo motor

Figure 3.0.2 shows where the distance measuring sensors are mounted. These two sensors are giving two independent distance measures and according to that garbage level is calculated.

Figure 3.0.2: Mounted ultrasonic sensors

Raspberry pi zero w board is the microcontroller used to perform every logical calculation. Each and every sensor and the servo motor connected to the microcontroller. As in figure 3.0.3 wired connection paths for every component is visible.

Figure 3.0.3: Raspberry pi zero w board

The system worked well after the testing phase. The research produced a usable, functional product, that allows new client registrations, functional client dashboard and admin dashboard. The system was simple enough to be understood and used by a person who had no technical knowledge of the system.

The system can be improved by adding a component to identify types of garbage from the bin itself, thus removing human segregation. If this is implemented, on a single location instead of four bins for the four different types of garbage, one large bin can be placed which segments the garbage by itself.

Another area which can be improved is instead of each bin connecting to an access point to communicate with the server, bins can communicate with each other and connect to an access point through a main hub. This method may reduce network costs and make the network process more efficient.

Normally cleaning trucks should clean in Figure 3.0.4 all garbage bin. because of they don't know what are the bins should clean or should not clean. Then they cover all bin in relevant zone. Likewise covering whole zone this method can affect lot of disadvantage for workforce user and also governments.

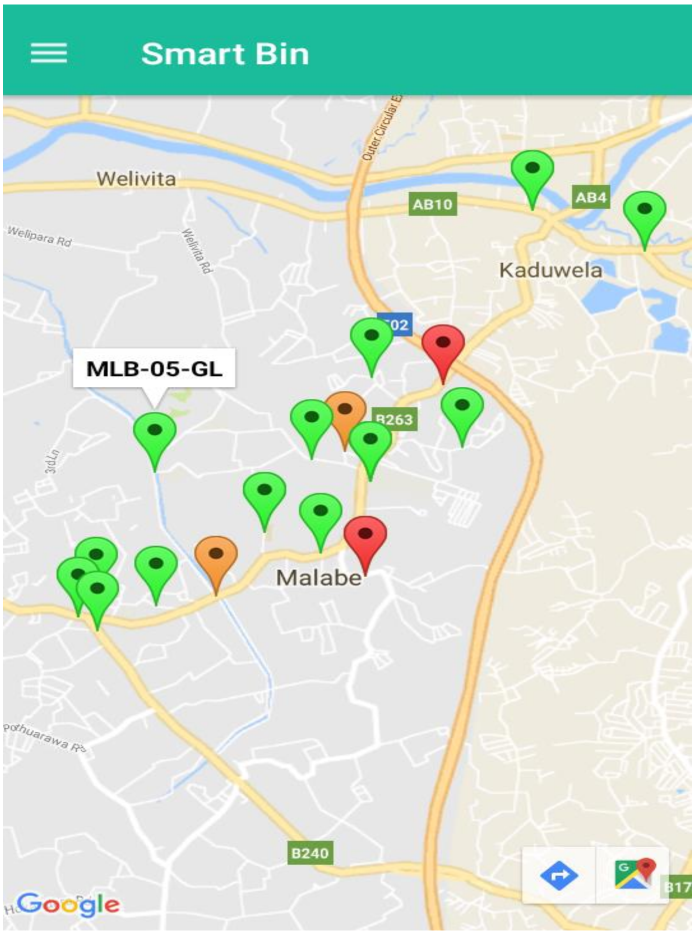


Figure 3.0.4: All garbage bin map

According to the Figure 3.0.4, cleaner should clean orange colour and red colour bin and bins which is coming from current bin level. As an example, "MLB-05-GL" bin should not clean according to the route calculation algorithm. It will help to save cleaner's time and cost of fuel which is spent by government.

As a result of author proposed route calculation algorithm, cleaning staff can identify recent situation of bin level and can identify situation of bin level after few hours. Using this method, lot of garbage bins will available long-time period to dispose garbage for citizen in the smart city.

According to the Figure 3.0.1 and Figure 3.0.2, black circled bins add into best route using recent bin level and red circled bin which is bin ID “MLB-13-Pl” add into best route using prediction.

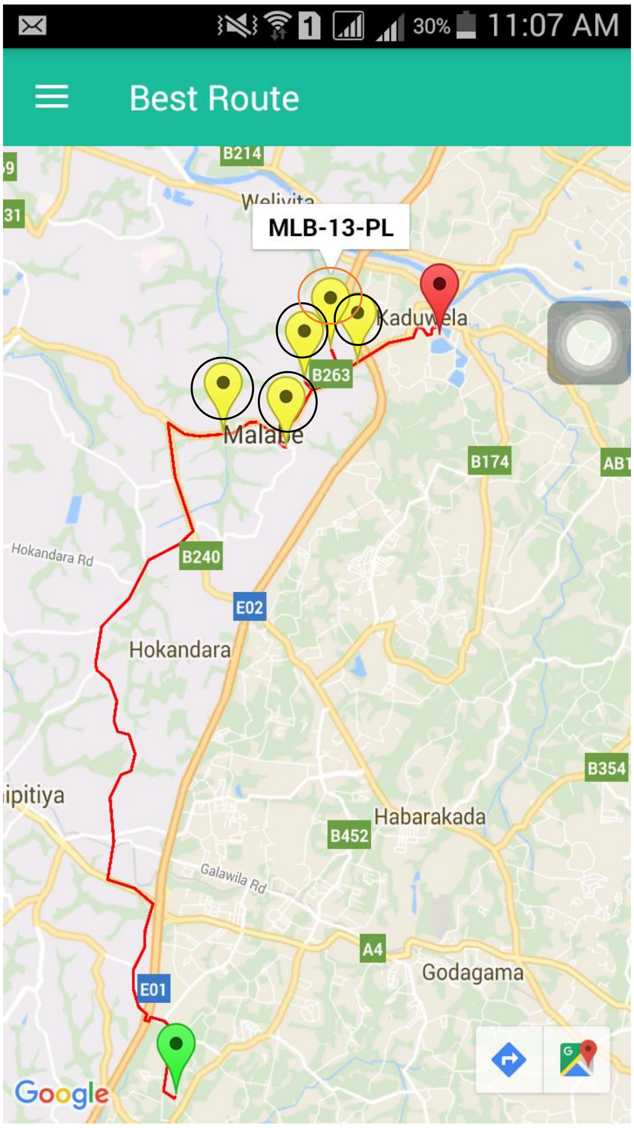


Figure 3.0.2: Best route

4.0 SUMMARY OF EACH STUDENT'S CONTRIBUTION

- **G.S.B. Dabarera**

1. Hand Gesture System
    - Lid open
    - Lid close
2. Garbage Level Measurement System
    - Garbage level detection
    - Upload garbage level to server
3. Safety System
    - Enable bin Operations
    - Disable bin Operations
4. Statistical Fault Detection (Research component)
    - Check sensor faults
    - Notify through website

- **R.K.R. Ranaweera**

1. Setup the server
2. The website
    - The Home Page
    - Sign-in Page
    - Client Sign-up Page
    - Admin Dashboard
    - Client Dashboard
3. The Analysis of Municipal Solid Waste Generation (Research component)

- **P.G.D.M. Perera**

1. Workforce user route Calculation (Research component)
    - Develop prediction algorithm
    - Create suitable database
    - Develop java program to dynamically update database
    - Write shell script to run java program on schedule
    - Pass best route details android application
2. Workforce user android application
    - Bin location map activity
    - Best route map activity
    - Bin details activity
    - Disabling/enabling security system switch
    - User login activity
    - User profile activity
    - User profile update activity
    - Cleaning history activity
    - Working history activity

- **P.A.V.D.R. Panangala**

1. Feedback Analyzer (Research component)
    - Feedback Analysis
    - Querying data
    - Provide efficient result
2. Bin analyzing system
    - Provide number of bins need for city
3. End user android application
    - User Registration
    - User login
    - Real time bin detail visualizer
    - Route calculation
    - User feedback with SMS

5.0 CONCLUSION

This article incorporates IOT solutions to implement a system that provides the municipal council with a system that better equips them to handle the garbage problem in a smart city. Every party is interacting with this system, that is the citizens, the workforce and the admins. Citizens can interact through the android application and the website, workforce through the app and the admins through the website.

Mainly this system is aimed at a city with a high or growing population. This system is built to adapt to growing populations. That is, when a specific position is overwhelmed by garbage, this system is alerted automatically or a client can complain about it, then an administrator is notified and extra bins are added until the number of bins are sufficient. The system also makes sure that bins are not located where they are not needed or too much bins are not located in the same place.

By the method the garbage trucks use to get routes makes sure that bins are never overflowing. The trucks do three rounds per day and cleans bins that are going to be filled between time periods. This optimizes the garbage collection method to be efficient by ensuring that every bin in the region is cleaned before they are filled unless under special circumstances.

The government can use this system to keep an eye on the levels of use of harmful materials, and apply techniques to reduce these uses if there are unhealthy upticks in the use of these materials. They can also use this system to confirm that the applies techniques are actually effective or a waste of resources. The government can setup recycling stations as another method of reducing pollution if the upticks in use of harmful materials cannot be controlled. The profit to be gained from these recycling can also be generated from the system itself.

All these components of the system ultimately lead to a cleaner city, citizens getting a convenient method to dispose of their day to day garbage and the government saving resources and even making a profit from recycling in the long term.

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7.0 Appendices

Raspberry pi zero specification is displayed in the table 7.0.1.

Table 7.0.1: Raspberry pi zero specification

Type	**Model A**	**Zero**
Memory (SDRAM)	256 MB (shared with GPU)	512 MB (shared with GPU)
USB 2.0 ports	1 (direct from BCM2835 chip)	1 Micro-USB (direct from BCM2835 chip)
Video input	15-pin MIPI camera interface (CSI) connector, used with the Raspberry Pi camera or Raspberry Pi NoIR camera	None

Python:

Raspberry Pi Python Code Library

- Adafruit_ADS1x15
- Adafruit_ADXL345
- Adafruit_BMP085
- Adafruit_CharLCD
- Adafruit_DHT_Driver