# LOCATION BASED GARBAGE MANAGEMENT SYSTEM WITH IOT FOR SMART CITY

Paththini Gamage Dinusha Madusanka Perera

IT14008306

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

Department of Information Systems Engineering

Sri Lanka Institute of Information Technology
Sri Lanka

October 2017

# LOCATION BASED GARBAGE MANAGEMENT SYSTEM WITH IOT FOR SMART CITY

Paththini Gamage Dinusha Madusanka Perera

IT14008306

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

Department of Information Systems Engineering

Sri Lanka Institute of Information Technology
Sri Lanka

October 2017

# DECLARATION

I declare that this is my own work and this dissertation1 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 my 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.

Also, I hereby grant to Sri Lanka Institute of Information Technology the non-exclusive right to reproduce and distribute my dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Name: P.G.D.M.Perera

……………………….. ……………………..

Signature Date

The above candidate has carried out research for the B.Sc. Special (Hons) degree Dissertation under my supervision.

Supervisor's name: Ms.Shashika Lokuliyana

………………………………. ………………………

Signature of the supervisor Date

# 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 recent garbage collection system includes routine garbage trucks doing rounds daily or weekly in the city. But that trucks don't cover every zone of the city that is needed to clean and also it will be covered some garbage bins which aren't needed to clean. As a result of above cases will be wasted workforce's time and fuel in the trucks. Then it can be reason for inefficient use of government resources and unpleasant environment.

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 smart 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 which provides the generated routes for the workforce.

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

# ACKNOWLEDGEMENT

I 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. I 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, I would like to thank my research group members as well as all the other friends who supported me and encouraged me throughout this project.

Finally, I would like to express my special thanks to my parents for their support and encouragement throughout my 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 |

# 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 Cruisers: A Public Automotive Sensing Platform for Smart Cities (2016) [5]

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.

### 1.2.2 Top–k Query based Dynamic Scheduling for IoT-enabled Smart City Waste Collection (2015) [8]

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

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 1.2.2.1: Dynamic Scheduling Algorithm

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 1.2.2.1) 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.

### 1.2.3 IOT Based Smart Garbage alert system using Arduino UNO (2016) [9]

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.

The overall flow diagram of the proposed model is shown in Figure 1.2.3.1.

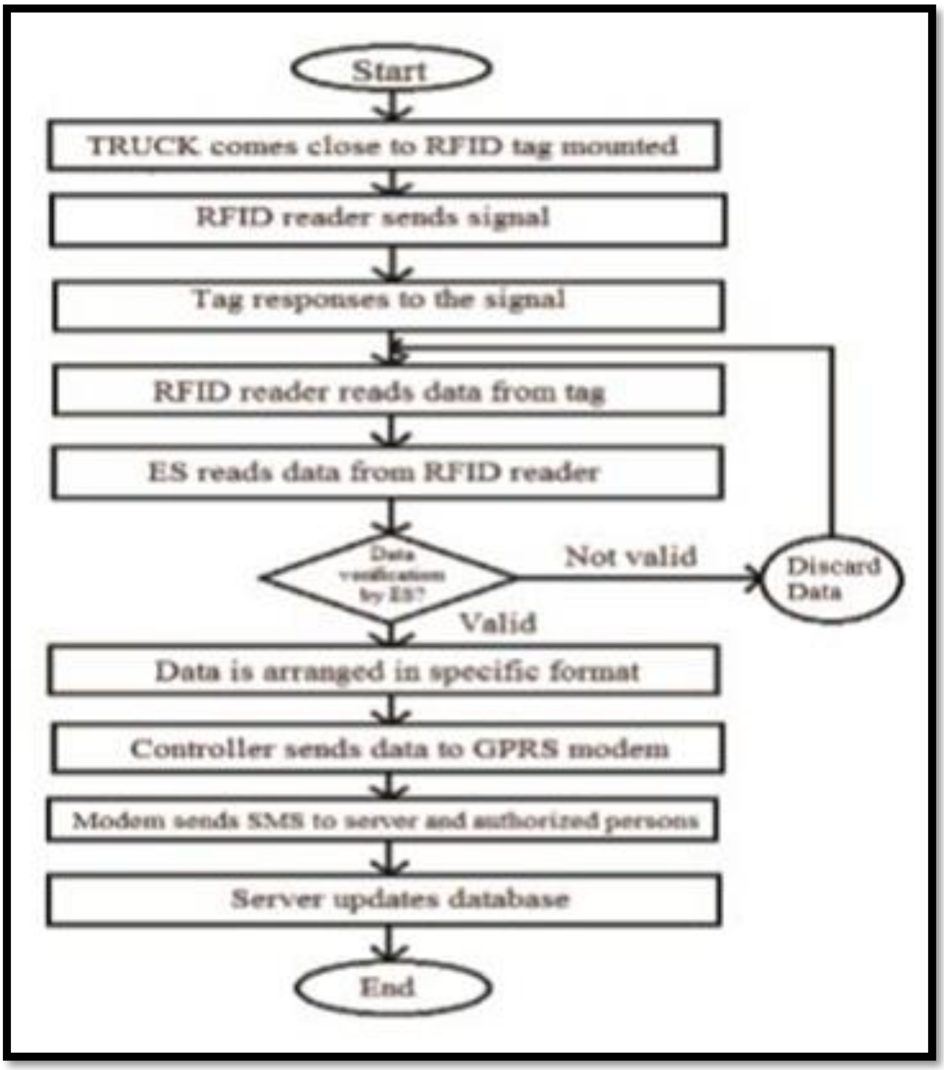


Figure 1.2.3.1: System Structure

## 1.3 Research Gap

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 [3], Smart Bin Implementation for Smart Cities [3] has used an android application to notify cleaners, a Cloud Computing Based Smart Garbage Monitoring System [4] 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 [4].
- 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 [5].

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

## 1.4 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 [6], the total amount of garbage collected in 311 local authorities was 2838 metric tons per day [6], which amounts to an annual garbage collection of 1.04 million metric tons per year. This is only 23% [7] 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 [7] on daily collection and disposal of garbage.

## 1.5 Research Objective

### 1.5.1 Main Objective

- 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 Objective

With the increase in population, the scenario of cleanliness with respect to garbage management is degrading tremendously. The overflow of garbage in public areas creates an unhygienic condition in the nearby surrounding. It may provoke several serious diseases amongst the nearby people. It also degrades the valuation of the area. To avoid this and to enhance the cleaning, 'Location Based Garbage Management System with IOT for Smart City' is proposed in this project. The main objective is to make a better place for humans to get there day to day work done in a smart city.

- User Satisfaction:

By adding specific features this system hopes to motivate people to use garbage bins instead of littering garbage here and there.

- Environmentally Effective:

Garbage management system must be able to protect and reduce the environment from improper disposal of waste that can cause hazard (emissions to land, air and water, such as $CO_2$, $CH_4$, CO and heavy metals).

- Economically Affordable:

The co-operative management should be able to afford the cost placed on garbage management operations by waste management system. This means that the cost of effective waste management system should consider the living standard of people in such community.

- Socially Acceptable:

For garbage management system to operate effectively, public cooperation is important. Moreover, the municipal council should always try to provide vital information, educate, develop trust and gain support from the community. Provision of bins or containers for collection and sorting of waste is another means by which recycling can be effective in the communities.

# 2.0 METHODOLOGY

## 2.1 Methodology

The proposed location based garbage management system has two types of users. These users are workforce user (Cleaner) and citizens. Among these users, work force user has lot of responsibilities to perform usually. The proposed location based garbage management system provide a workforce application with route calculation algorithm to fulfill their responsibilities very easily. The workforce application can be broken into two main function.

1. Android Application Development
2. Route calculation algorithm

### 2.1.1 Android Application Development

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. Best route

### 2.1.1.1 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 2.1.1.1.2).

There are four type of garbage bins at one location. (Figure 2.1.1.1.1)

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.

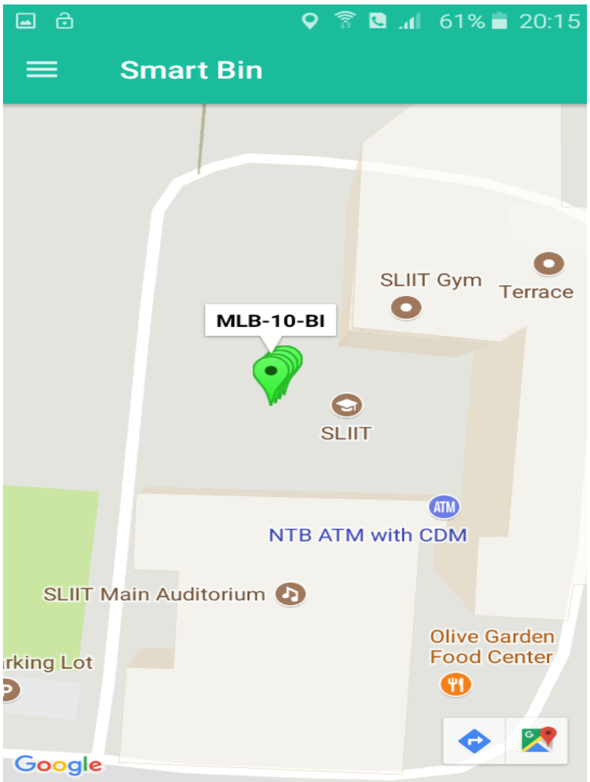


Figure 2.1.1.1.1: Four type of bin each place

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

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

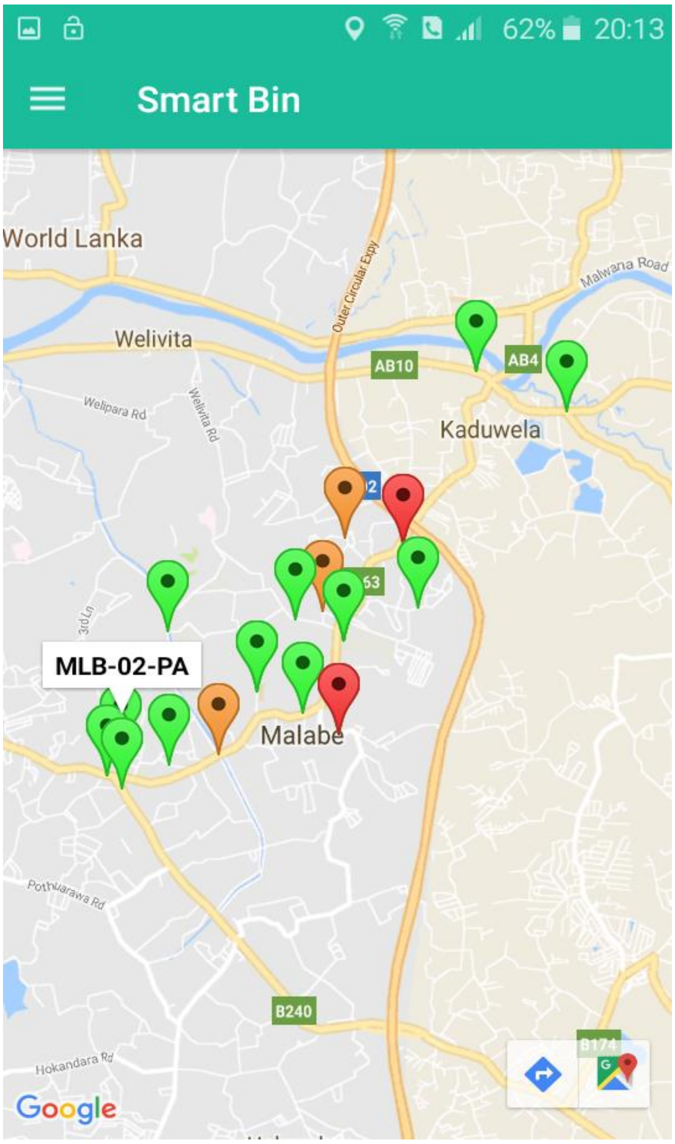

Figure 2.1.1.1.2: All bin location map

### 2.1.1.2 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 2.1.1.2.1), 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.

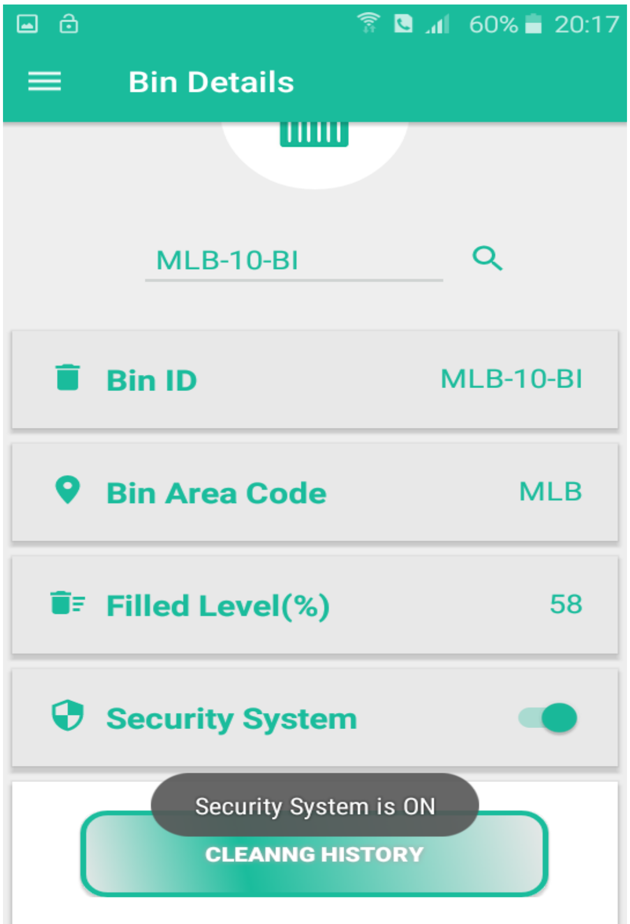


Figure 2.1.1.2.1: Bin details

#### 2.1.1.3 Best route

The figure 2.1.1.3.1 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 2.1.1.3.2).

The author uses GPS or network based tracking system to provide current location and provide best route. In figure 2.1.1.3.2 green colour marker indicate current location of cleaner and red colour marker indicate end point which is disposal point for collected garbage.

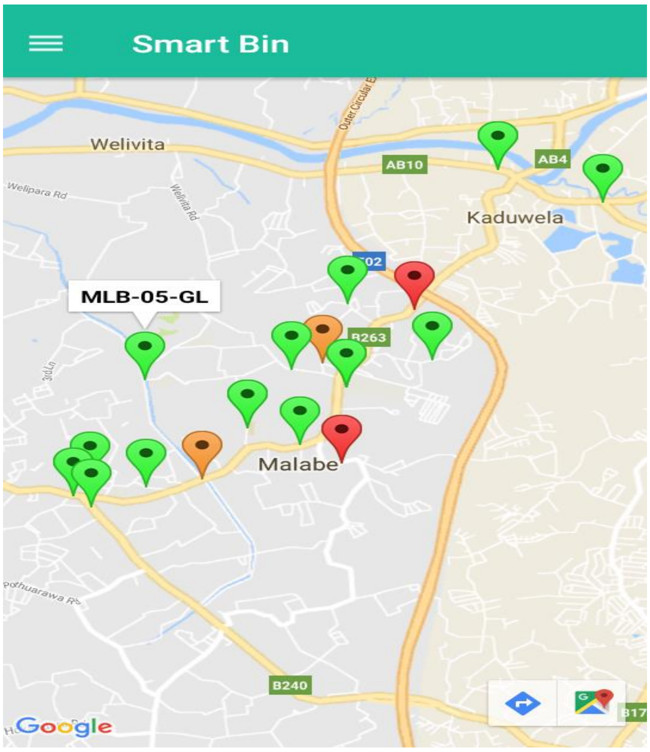


Figure 2.1.1.3.1: All bin location

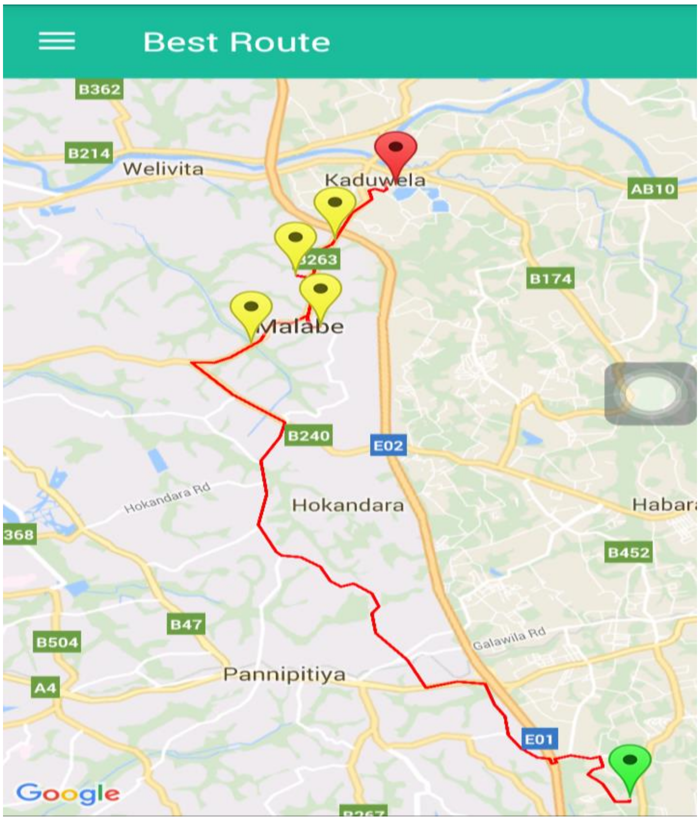


Figure 2.1.1.3.2: Best route map

### 2.1.4 Other Features

**Cleaning History**

There is a button in the bin details interface (Figure 2.1.1.2.1) 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 2.1.1.4.1) provide cleaner name, date and time which has been sorted descending order of date and time.

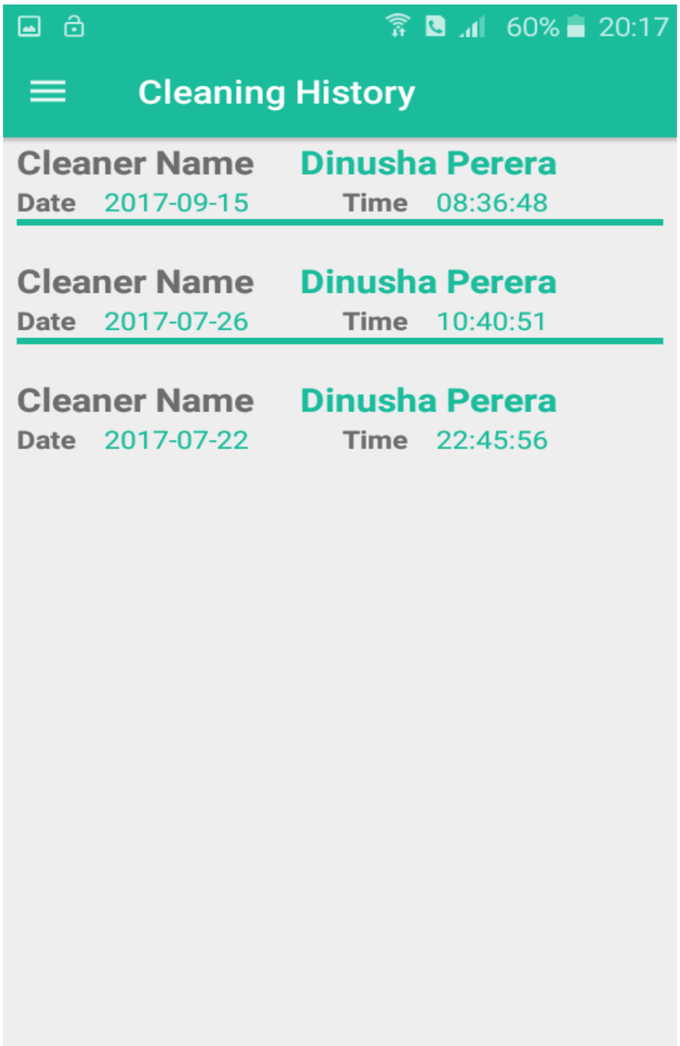


Figure 2.1.1.4.1: Cleaning history

**Working history**

The cleaners can see their cleaning history through clicking navigation drawer (Figure 2.1.1.4.2) working history item. The working history interface (Figure 2.1.1.4.3) provide bin ID, Area name, date and time.

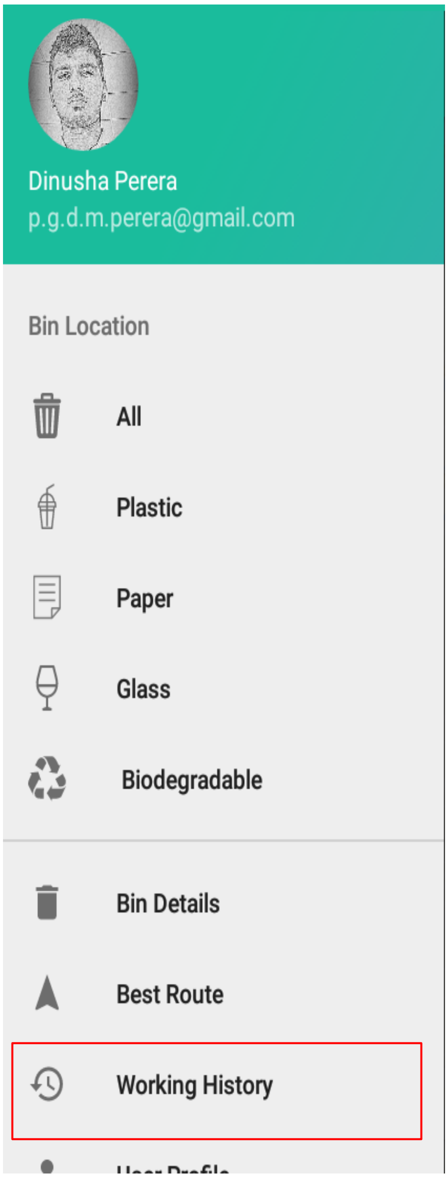


Figure 2.1.1.4.2: Navigation drawer

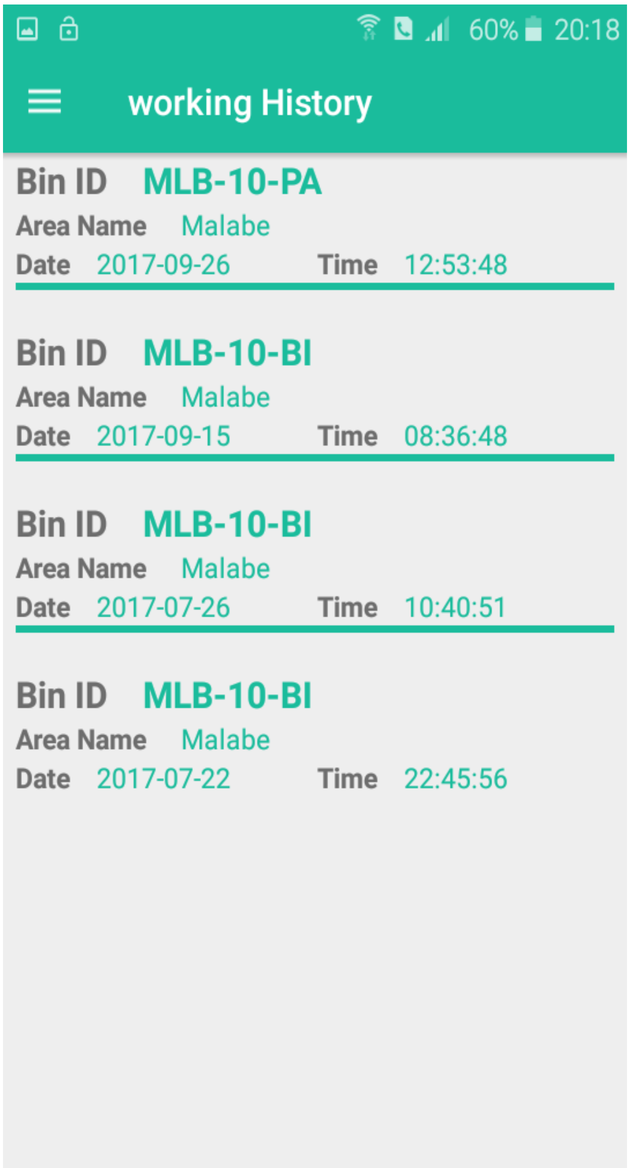


Figure 2.1.1.4.3: Working history

### 2.1.2 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 2.1.2.1).

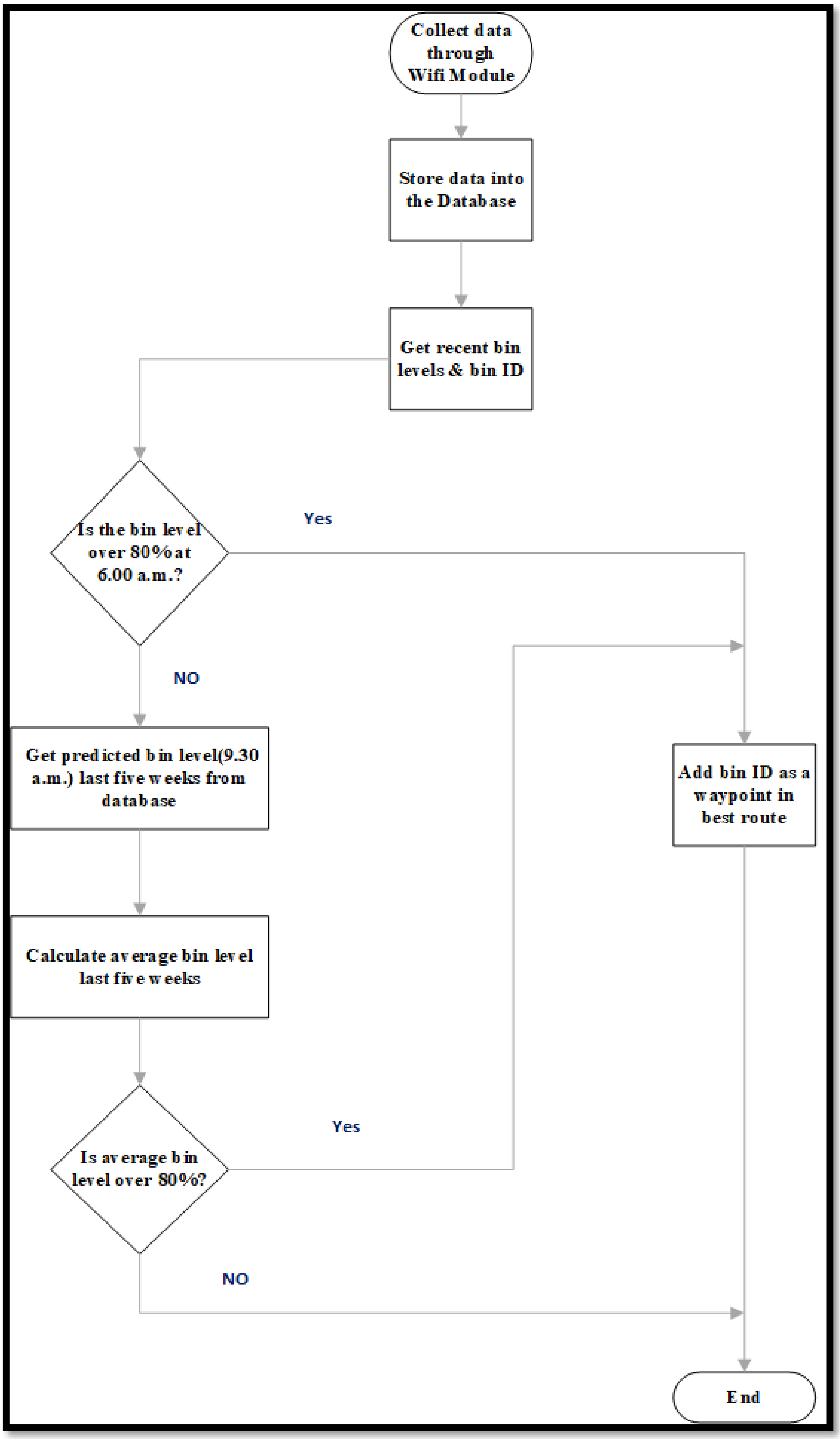


Figure 2.1.2.1: Add a bin as a waypoint – Flowchart

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:

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

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

Table 2.1.2.1: 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 2.1.2.2: Calculation Table (Method 1)

| **x** | **f(x)** | **Δf** | **$\Delta^2$f** | **$\Delta^3$f** | **$\Delta^4$f** | **$\Delta^5$f** | **$\Delta^6$f** |
|---|---|---|---|---|---|---|---|
| 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 2.1.2.2: 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 2.1.2.3: 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

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 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. Smart city must have Wi-Fi enable all the time. 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

Table 2.2.2.1: 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<br><br>2. Fill the text box.<br><br>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 2.2.2.2: 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.<br><br>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 2.2.2.3: Test case 03

| | |
|---|---|
| Test ID | 03 |
| Description | User can see suitable path for collect garbage |
| Pre-condition | Connect to Wi-Fi or mobile network.<br><br>Login to android application and enable GPS |
| Actors | Cleaner |
| Main Flow Events | 1. Login to android application<br>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 2.2.2.4: Test case 04

| | |
|---|---|
| Test ID | 04 |
| Description | Disabling/Enabling security system |
| Pre-condition | Connect to Wi-Fi or mobile network.<br><br>Login to android application. |
| Actors | Cleaner |
| Main Flow Events | 1. Login to android application<br>2. Go to the bin details interface |

| | |
|---|---|
| | 3. Search needed bin<br>4. Click change status switch |
| Expected Output | Security system enable or disable |
| Actual Output | Security system enable or disable |

Table 2.2.2.5: 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.<br><br>Login to android application. |
| Actors | Cleaner |
| Main Flow Events | 1. Login to android application<br>2. Go to the bin details interface<br>3. Search needed bin<br>4. Click cleaning history button |
| Expected Output | Display cleaning history |
| Actual Output | Display cleaning history |

Table 2.2.2.6: 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.<br><br>Login to android application. |
| Actors | Cleaner |
| Main Flow Events | 1. Login to android application<br>2. Go to Navigation drawer<br>3. Click “working history” item |
| Expected Output | Display working history |
| Actual Output | Display working history |

# 3.0 RESULTS AND DISCUSSION

## 3.1 Results and Discussion

Normally cleaning trucks should clean in Figure 3.1.1 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.

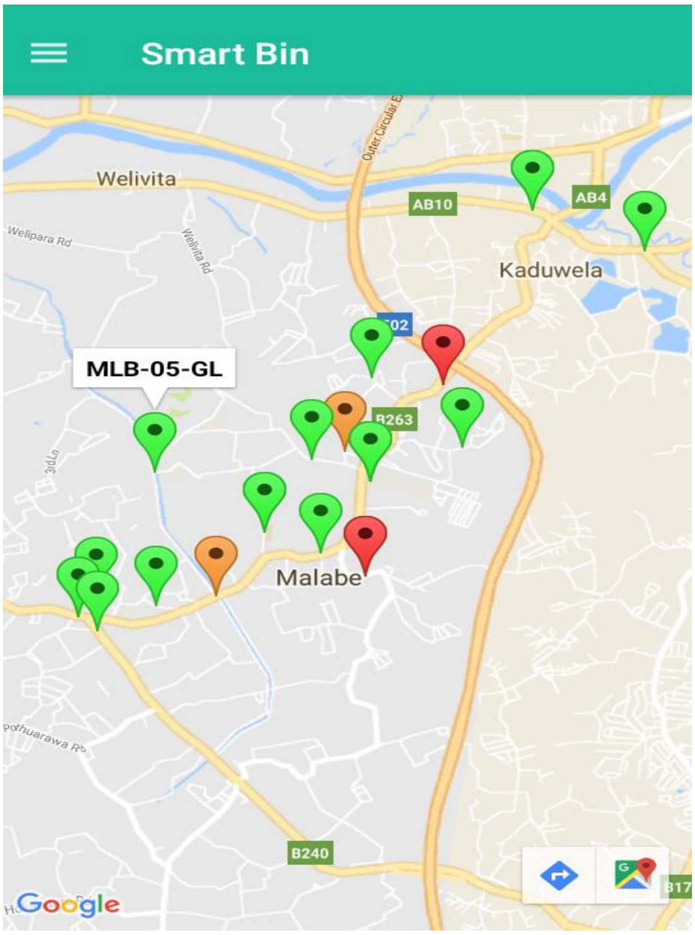


Figure 3.1.1: All garbage bin map

According to the Figure 3.1.1, cleaner should clean orange colour and red colour bin and bins which is coming from predicted future 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 3.1.1 and Figure 3.1.2, 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.

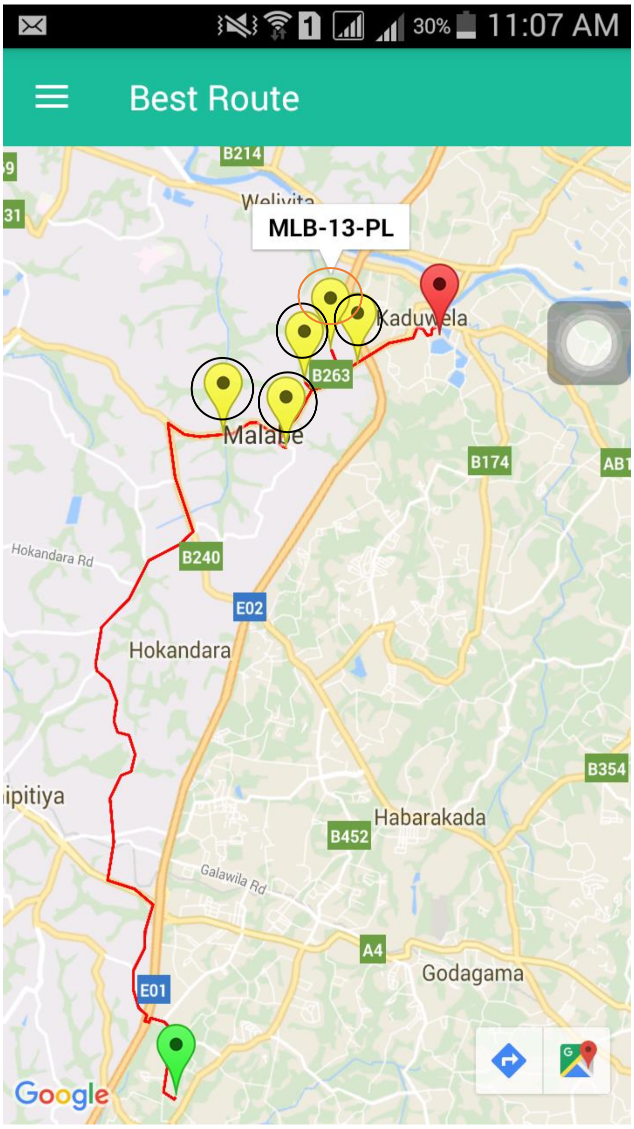


Figure 3.1.2: Best route

## 3.2 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.

Lot of research papers try to provide various solution for garbage management. But that papers not provide better solution for collect garbage in the city. Therefore, author try to provide optimized route as a main outcome through this research paper. As well as author hope to provide overall locations of garbage bins in the city, behavior of the best route and protect the database when passing unwanted data during cleaning process of garbage bins through the workforce mobile application

# 4.0 CONCLUSION

This research work demonstrated best route to collect garbage in smart city with route calculation algorithm and provide mobile application to workforce users. This route calculation algorithm clearly identified what are the bins should clean and what are the bins should not clean. The entire garbage collection domain is optimized through this new garbage collection technique. This algorithm provides lot of advantages about both parties which are involved in cleaning process and government who is spent money. Both parties get their ultimate expectation, benefits on the perspective of garbage management. As well as providing better garbage collection, the government can maintain healthy environment and it will be a foundation to make healthy citizens. This facilitates to initiate, continual improvement and constant garbage management in smart city.

In the future can increase the effectiveness of route calculation to enhance the best route.

# 5.0 REFERENCES

[1] "Colombo Vehicle Statistics (2015)." Indi.ca. [Online]. Available: http://indi.ca/2015/10/colombo-vehicle-statistics-2015/. [Accessed: 09-Jan-2017]

[2] "Population and Housing." Population and Housing. [Online]. Available: http://www.statistics.gov.lk/page.asp?page=Population%20and%20Housing/. [Accessed: 09-Jan-2017]

[3] Narayan Sharma, Nirman Singha, Tanmoy Dutta, Smart Bin Implementation for Smart Cities, International Journal of Scientific & Engineering Research, Volume 6, Issue 9, September-2015, pp. 787- 791.

[4] J. Joshi *et al*., "Cloud computing based smart garbage monitoring system," *2016 3rd International Conference on Electronic Design (ICED)*, Phuket, 2016, pp. 70-75.

[5] Y. Chen, J. Nakazawa, T. Yonezawa, T. Kawsaki and H. Tokuda, "Cruisers: A Public Automotive Sensing Platform for Smart Cities," *2016 IEEE 36th International Conference on Distributed Computing Systems (ICDCS)*, Nara, 2016, pp. 767-768.

[6] "Hobbyist.co.nz." Infrared Proximity Sensor | Hobbyist.co.nz. [Online]. Available: http://www.hobbyist.co.nz/?q=infrared_proximity_sensor/. [Accessed: 23-Jan-2017]

[7] "National Solid Waste Management Support Center." National Solid Waste Management Support Center « Ministry of Provincial Councils and Local Government. [Online]. Available: http://www.lgpc.gov.lk/eng/?page_id=1118/. [Accessed: 03-Jan-2017]

[8] T. Anagnostopoulos, A. Zaslavsky, A. Medvedev, S. Khoruzhnikov, "Top-k Query based Dynamic Scheduling for IoT-enabled Smart City Waste Collection," In Proc. of the 16th IEEE International Conference on Mobile Data Management (MDM 2015), Pittsburgh, US.

[9] N. S. Kumar, B. Vuayalakshmi, R. J. Prarthana and A. Shankar, "IOT based smart garbage alert system using Arduino UNO," *2016 IEEE Region 10 Conference (TENCON)*, Singapore, 2016, pp. 1028-1034.

[10] Android Architecture [online] Available: http://senda.uab.es/node/15 [Accessed 26-Apr-2017]

[11] Android Flatforms [online] Available: https://developer.android.com/about/dashboards/index.html [Accessed 26-Apr-2017]

[12] "Waypoints in directions | Google Maps JavaScript API | Google Developers." Google Developers. [Online]. Available: https://developers.google.com/maps/documentation/javascript/examples/directions-waypoints/. [Accessed: 15-Mar-2017]