Easy Clean – A Smart Solution for Garbage Finding and Collecting

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ABSTRACT
Efficient Solid waste management is one of the key factors of development of a nation. The purpose of this project is to develop an efficient waste management system based on Internet of Things (IoT). In line with that, the project team has observed traditional waste management system of Sri Lanka and have identified a number of issues with current systems. They are, unhygienic landfills, overflowing waste bins, limited collection, lack of storage in collection vehicles and less awareness of separated waste collection, recycling and reuse. Easy Clean System has been proposed as a solution to cope up with the above issues. Easy Clean provides a platform for domestic users, drivers of collection vehicle and garbage collection authority to interact with solid waste management of the country. This was achieved with the use of various sensors such as load cell sensors, ultrasonic sensors and Global Positioning System (GPS) module to track location and status of bins, GSM/GPRS shield for data transmission and Arduino MEGA 2560 to interface all the above hardware units. The desktop application has been developed to provide centralized management for the collection authority. Easy Clean Android Application has been developed to connect domestic user, collection vehicle drivers, and the central management. Easy Clean will drastically increase the efficiency of solid waste management by providing the cost-effective computer aided system.

Keywords
Solid waste management, Internet of Things, load cell, ultrasonic, GPS, GSM/GPRS, Arduino MEGA, Android

1. INTRODUCTION
Solid waste generation has become a key challenge for the countries in the world. There are many reasons for this enormous increase in waste quantities, such as the population, urbanization, and migration of population from the rural to the urban areas leading to much higher population densities, changes in lifestyles and economic activities. Sri Lanka, the statistics states that daily 3,242 metric tons were collected by the local authorities. Expenditure on solid waste from the local authorities in Sri Lanka is about US$27 million [1]. More than 125 local authorities have been provided with financial and technical support to implement recycling program over the nation.
But, a vast amount of solid is being denied by these authorities due to improper separation [2].
To cope up with the above issue the project team has developed an effective solid waste management system for house based garbage collection.

Easy Clean is an effective solid waste management system developed using smart bins, mobile applications for domestic users and collection vehicle drivers and a desktop application with a database for the governing authorities. Smart bin has been designed to receive and transmit real-time data about bin status to the main server. This data will be manipulated and stored by the system to address the requirements of local authority and other users. Features such as Real-time monitoring, garbage collection scheduling, maintenance of information and reports have been enabled with the use of a centralized desktop application. Furthermore, Mobile application provides cost effective collection routes, schedules, and notifications for the drivers whereas domestic users are provided with bin status and collection notifications. The suggested Easy Clean System ultimately minimizes the issues related to solid waste management by providing cost effective route plans and user-friendly applications for Centralized management.

The remainder of the paper follows as below. In section 2, the existing literature available with similar kind of studies has been analyzed. Section 3 describes each phase of development methodology in detail. The results of the research and their discussions have been described Section 4 of this paper. Finally, Section 5 concludes with the conclusion and future works of this research area.

2. BACKGROUND STUDY
Nowadays people are more likely to engage their works with modern technologies. According to that, the concept of IOT is spreading very rapidly and it is used for various purposes. Thus, researchers have been focusing on waste management with the use of modern technologies from last two to three years. As a result of that lots of research papers have been published on developing a proper IOT based waste management as well as collection system.

Sensors have been used to get the fill level of the garbage whereas GSM modules have been used to transfer required data to control room. The Arduino microcontroller interfaces between the sensor systems and GSM module. Overall monitoring and maintenance of garbage related information have been achieved through user-friendly interfaces. A unique ID has been provided for each garbage bin available in the city so that it was easy to identify which garbage bin is full. When the garbage level reaches the limit, the device had transmitted the level along with the unique ID provided. These details will be then accessed by the authorities from their place through Internet and an immediate action will be made to clean the dustbins. Benefits of this system are cost reduction and resource optimization, intelligent management of the services in the city and effective use of dustbins [3] [4].

Then, another research article on Door to door garbage collection tradition was studied. Here research has been made to ensure zero garbage level with services at minimum cost. ARM 7 Controller was sending short message service to the cleaner to clean the dustbin. When dustbin was filled then, SMS sent to cleaner by using Global System for Mobile [5].

Then, an integrated system which is combined with an integrated system of ZigBee and Global System for Mobile Communication (GSM). Garbage bins in public places have been targeted in this research. When the garbage reaches the level of the sensor, then that indication had given to ARM 7 Controller. The controller will then notify the driver of garbage collection truck so as to get immediate attention. ARM 7 used GSM technology to send out the SMS to the driver. ZigBee technology for garbage bin detail and real time monitoring of garbage bins and information transfer, resource optimization and truck monitoring system used GSM [5] [6] [7].

There were many systems developed and contributed to reduce the pollution in the city, stop many health problems for the citizens and reduce the fuel consumption of the trash van. The locations of the trash bins also could be identified easily via those systems [8] [9] [10].

Calculate the distance traveled two stations with web application via Google map. Then message transmission time and position were at that time. These systems should have a service provider contract. Another Automated smart garbage collection technique has been suggested using Image processing and GSM for data transfer. When garbage filled then cleaner can collect the garbage. These systems can reduce the productivity of the vehicles and manpower. Those didn't mention the following features, need electricity anytime and these systems can only see the garbage fill level and weight [11] [12].

Then, identified that garbage removal and management of removable garbage were performed the main role to improve the health of the people [13].

It explained about managing the waste collection system of an entire city. The project gave one of the most efficient ways to keep our environment clean and green. Research brought clarification about the waste management in urban areas and it targeted at encouraging further research on the topic of waste management. Then research provided ideas to stop overflowing of dustbins along roadsides and localities [14].

GPS-based navigation systems are common in a variety of land-based vehicles. Enough explanation and ideas about GPS got from these research. Reviewed impact that individual navigation sensors had on the performance of a land-vehicle navigation system. It helped to know the different difficulties, implementation regarding GPS system in various applications and identified some issues on each application [15] [16].

Dispose of the waste with Wireless Sensor Networks (WSN) using VANETs. It was the easy way for long distance communication without GSM module as well as the driver could easily understand where garbage was filled. Methodologies such as Vehicular Ad-Hoc Networks (VANETs) was used to provide communication between the vehicles. Then sensors were used to estimate the filled level [17].

3. METHODOLOGY

Section 3 discusses about each phases of prototype methodology which has been used for the development of Easy Clean System, procedures of tasks in each phase and materials produced at each phase of System Development Lifecycle.

3.1. Planning

Initials planning for successful development of Easy Clean System was carried out in this phase. The project team identified the need for Easy Clean System by studying the issues with tradition solid waste management system. Eventually, Work Breakdown Structure (WBS) and Gantt chart were developed to determine how the project team will go about building Easy Clean System. A feasibility study including economic, technical and organization was carried out to determine whether the system is feasible for solid waste collection authority.

3.2. Requirement Gathering and Analysis

Requirements were gathered as both primary and secondary data in order to analyze traditional solid waste management system in Sri Lanka and to identify research on similar products in the industry. Thus the basic concept for the new system was developed. Interview with district engineer of solid waste management department and online Questionnaires were used as tools to collect primary data whereas literature review was used as the tool to collect secondary data. Gathered information was severely analyzed to identify the users and basic requirements of the new system.

3.3. Design

Basic designs for Easy Clean System was sketched to determine exact operations required from Easy Clean System. Architecture Diagram, Hardware infrastructure diagram of smart bins, and interface designs of both desktop and android application were sketched. Decisions were made on hardware programming IDE, Android Development Kit, Desktop Application Platform and database servers to be used.

Fig 1 depicts the Architecture diagram of Easy clean system sketched at this phase and Fig 2 depicts the Hardware infrastructure diagram of Easy clean system sketched at this phase.

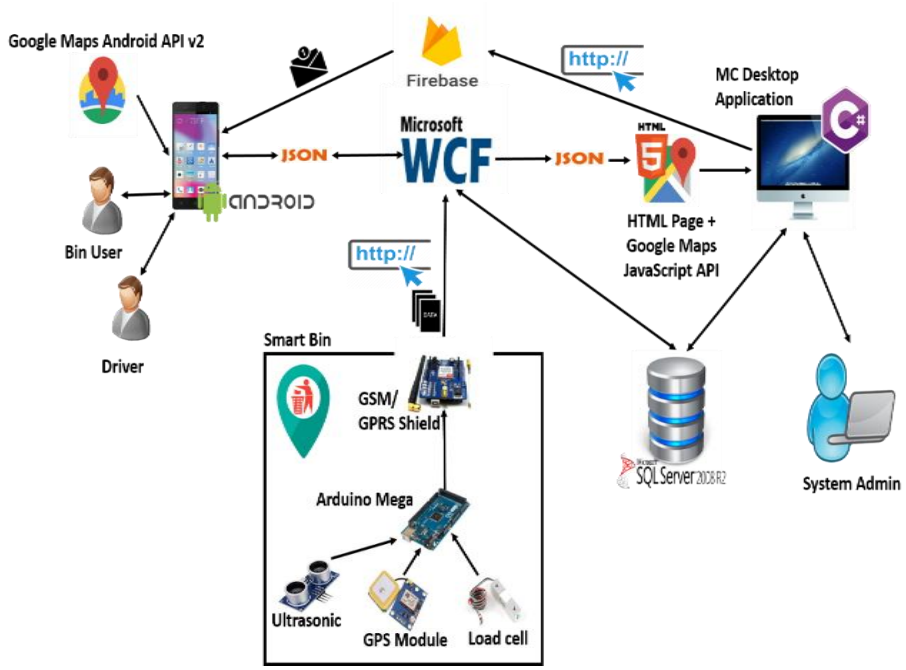

Fig 1 : Architecture Diagram

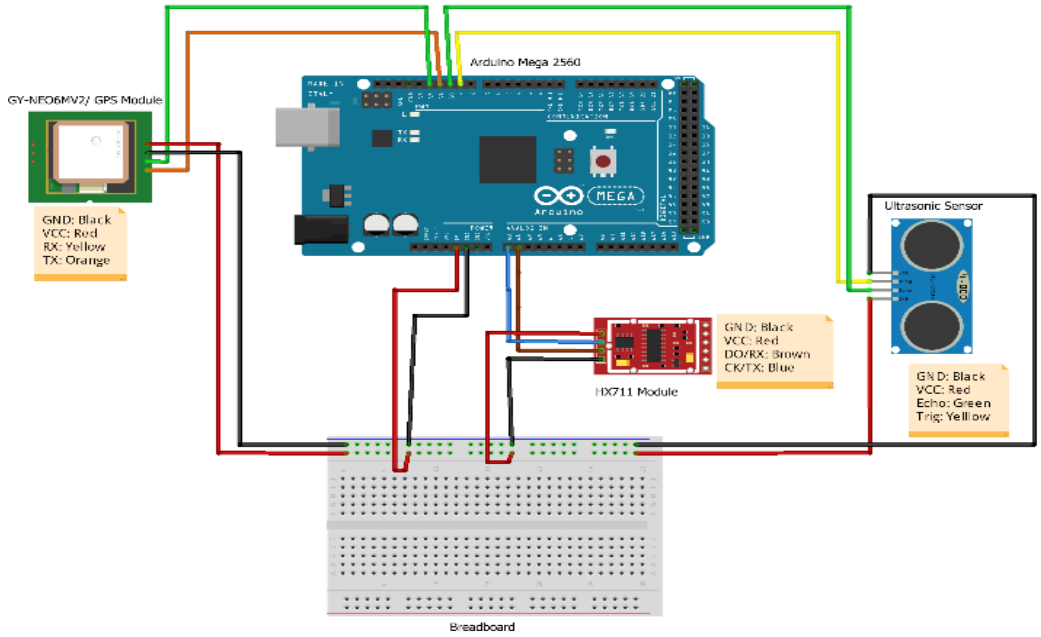

Fig 2 : Hardware Circuit Diagram

3.4. Implementation

Hardware assembling and programming were carried out to develop the outcome of designing phase. Load cell sensors, Ultrasonic sensor, GPS module and GSM/GPRS Shield were connected to Arduino MEGA 2560 and fixed to a waste bin during hardware assembling process. Arduino IDE was used to program Arduino Micro Controller in order to receive and transmit required information from the smart bin. Android Application, Desktop Application, and Web Service were developed in parallel using Android Studio and Visual Studio respectively. Firebase Server has been used with Firebase Cloud Messaging (FCM) notification service to send necessary notifications to Android Application. C#.NET, Micro C, C, and JAVA were used as programming languages. Microsoft SQL Server 2008 R2 has been used to develop a database for Easy Clean System whereas Windows Communication Foundation (WCF) with restful services has been used to manipulate database content.

3.5. Testing

Easy Clean System was tested by applying different test cases in this phase. Test cases were prepared to test each and every path available in the codes of Arduino microcontroller, Desktop application, and Android application. Unit testing, Integration testing, and System testing were carried out to ensure system reliability. Different units of the Easy Clean System were tested separately in unit testing whereas Integration of all the units as a whole tested during integration testing and system testing.

4. RESULTS AND DISCUSSIONS

Section 4 discusses the results and their discussion that the research team achieved from the research project. The important implications of the research findings, regardless of the statistical significance of this research are discussed below. Further, Identifying the defect and limitation of this project can be useful for future researchers in order to continue their research. The major object of "Easy Clean" is to provide an efficient solid waste management system to the society.

Easy Clean System comprises of three major components such as Smart Bin, Desktop application for municipal council and Android application for collection vehicle drivers and smart bin users.

Primarily, the Easy Clean smart bin is designed to read and transmit garbage level details such as height level and weight of collected garbage. Location of bins was also be read and transmitted to the main server. Fig 3 below shows design and hardware implementation of the smart bin.

Fig 3 : Smart Bin

The bin level readings and related details received from smart bins were manipulated in the main desktop application of municipal council to ensure proper waste management system. These bin statuses are also displayed in smart bin user's mobile application. Fig 4 below shows the mobile application interface which shows the bin status details.

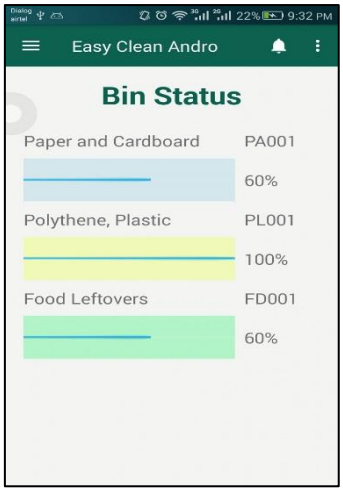

Fig 4 : Bin Status

Initially, municipal council authority registers customers, collection vehicle drivers, and collection vehicles, recycling companies, collection areas, collection routes, smart bins and respective Arduino boards. Fig 5 below shows the desktop application interface relevant to this process.

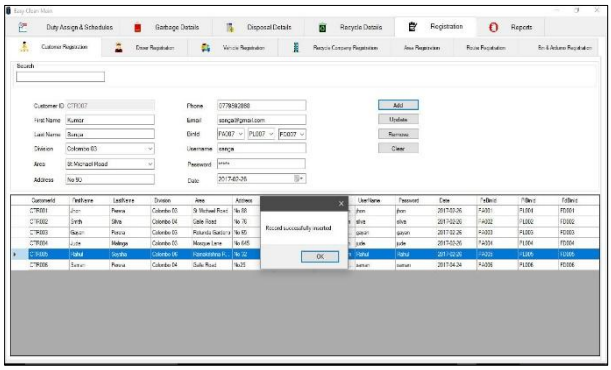

Fig 5 : Customer Registration

Next, municipal council authority carries out scheduling process. At first list of Collection areas for the day will be automatically scheduled by Easy clean desktop application considering collection program and past collection details once the Administrative staff assigns collection vehicle and driver for first collection area in each district. The task of assigning collection vehicle and driver is repeated whenever needed till the whole collection scheduled for that day ends. Fig 6 below shows Desktop application interface relevant to this scheduling process.

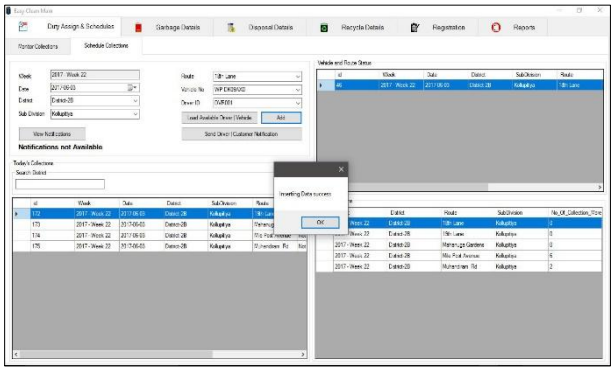

Fig 6 : Scheduling Process

Soon after collections are scheduled collection vehicle driver and smart bins users in collection areas are notified about the collection. Fig 7 below shows the notification received by the driver regarding the collection.

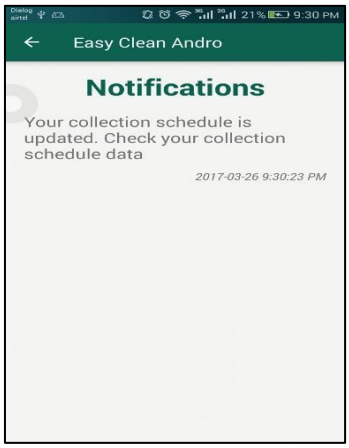

Fig 7 : Notification for Driver

Fig 8 below shows the notification received by the smart bin user regarding the collection.

Fig 8 : Notification for Bin User

Real-time monitoring about collections is achieved through Google map API embedded in the main desktop application. Whereas cost effective real time navigation routes for collection areas are displayed to the collection vehicle driver using Easy clean mobile application. Figs 9 and 10 below shows the main desktop application interface used for monitoring purpose and navigation route maps displayed to the driver in the Easy clean mobile application.

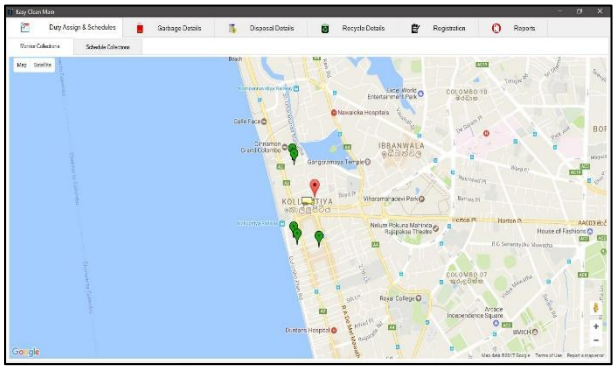

Fig 9 : Monitoring Process

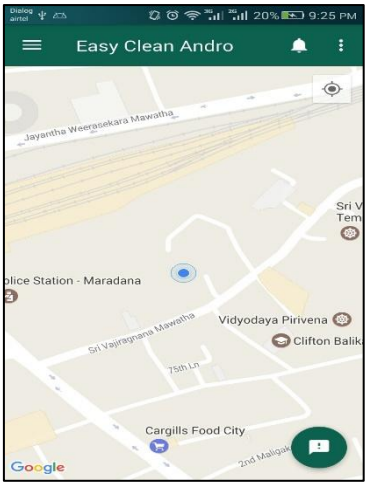

Fig 10 : Navigation for Driver

Finally, whenever garbage level reaches the max level driver notifies it to the main Authority and retrieves from the collection. Another notification is sent to the main desktop application once garbage is disposed from the vehicle and ready for next collection.

Soon after each and every collection, garbage collection details and stock details are updated to the main desktop application. Figs 11 and 12 below shows main desktop application interfaces which display collection details and garbage stock details respectively.

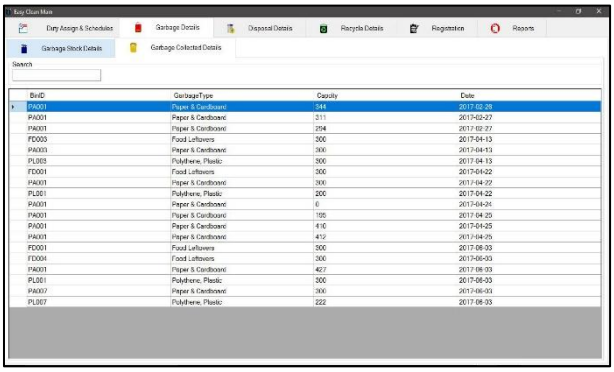

Fig 11 : Collection Details

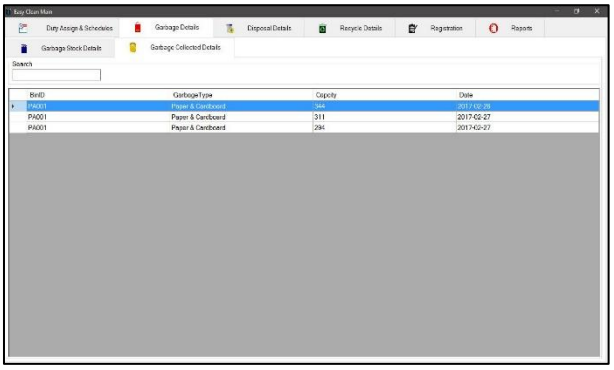

Fig 12 : Garbage Stock Details

Reports regarding garbage collection, disposal and recycles are generated by the main desktop application as per user selections of administrative staff. Fig 13 below shows the interface regarding report generation.

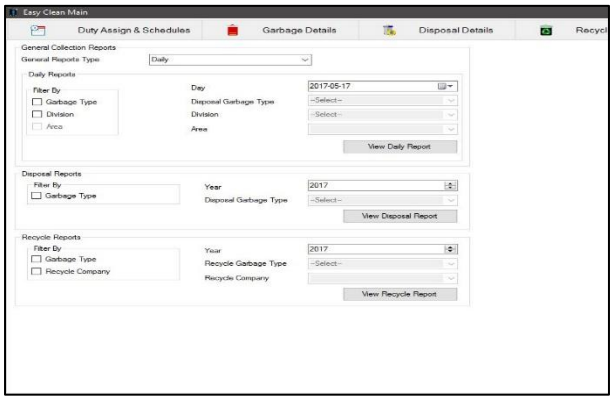

Fig 13 : Report Generation

Reliability of the system was tested under various test cases using various types of testing. Accordingly, the Easy Clean system has shown 95% of accuracy level and 80% of reliability level. This level of reliability has been achieved by carrying out various techniques to ensure proper solid waste management. Monitoring of overall garbage collection process, collection vehicle positions and fill level of domestic bins in real time makes the Easy clean system highly reliable. This real-time process has been achieved through secure real-time data transmission using WCF. Cost effective navigation maps and collection schedules in a user-friendly manner provides a reliable interface to the collection vehicles driver. Google Map Android API has been used to get cost effective routes to destinations (collection areas) for Easy Clean Android Application. Authentication verification using username and password when accessing the Desktop application and mobile application ensures security for basic authentication issues. Firebase tokenizing for each and every mobile with Easy Clean Android app has been used to ensure that no user prevails multiple accounts in multiple devices at the same time.

Project team encountered numerous technical problems during the lifetime of product development. The major problem that project team encountered was managing software serial between two gadgets. Calibrating load cell sensors to the max accuracy level and monitoring and replacing damaged circuit wires time to time were some other problems faced by the project team. Software serial was used for both GSM/GPRS shield and GPS module. Both modules use half duplex method for data transmission hence the project team found difficulties to make them work simultaneously. Later project team wrote a looping function so that both modules switch transmission in regular intervals. Load cell calibration was one of the tedious problem faced by the project team which took a huge amount of time during hardware assembling. Load cell sensors give random values as the output which differs with altitude even if the weight of the same object is measured. Initially, the project team was not aware of this issue as the team was hardly familiar with hardware programming. Soon after this issue was found load cell sensor was kept at the same altitude as in waste bin and calibrated. The project team found a rough equation for calibration by plotting known weights with load cell readings. The accuracy of reading was further refined by testing with minute changes.

5. CONCLUSION AND FUTURE WORK

Rapidly increasing population, urbanization, and industrialization have made Solid waste management a global challenge. The Easy Clean system provided comprehensive solutions to the people those who are in the urban area with smart garbage finding and collecting. This system could read and transmit current status of the bin to the server. Then manipulated information required for solid waste management using a centralized system. Developing mobile applications to assisted driver with the collection. Then notified domestic user prior to the collection through the mobile application. Reports related to the waste collection could be generated through this system. After that, enabled real-time monitoring of waste collection and easy scheduling also done via this system. Finally, the project successfully achieved to fulfill all the objectives of this system and hope this research would be of benefit. The research team hopes that this study will be helpful for the researchers who are interested in the topics like waste management, navigating systems as well as waste collection and findings. It will also give better ideas and more knowledge to implement similar kind of projects or hi-technical projects with more advanced tools.

During the development of this project, the following are the limitations identified:

1. Need data plan enabled SIM.

GSM/GPRS uses mobile sim data to transfer real-time data about bin status to the server. Therefore, data plan should be enabled in this case and recharging is needed to maintain an uninterrupted connection with the central MC server.

2. Limited battery life.

A 12v 8000mah li - ion battery has been used to power up Arduino circuit. It has a battery life of circular charge and discharges up to 500 times. The battery should be recharged in regular intervals for reliable functioning of Smart bins.

3. Less accuracy with GPS location readings.

Location of smart bins has been read using GPS module which needs at least 3 satellite connections to accurately read a location. Hence location read may be with less accuracy in case of fewer satellite connections.

4. Smartphone and basic knowledge are significant for Domestic user and Collection vehicle driver.

Till the goal has been met, a numerous number of research paths would be open to the researchers. This research area will stay fresh with the rise modern technologies. The project team has identified some immediate set of future works which may interest to the researchers in this area.

1. Integrating bins at public places to the system
2. Provide information regarding nearest public bins to domestic user
3. Developing the mobile application with multi-platform support and expand the system targeting waste management of the entire nation.

6. ACKNOWLEDGEMENT

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