# SMART WASTE MANAGEMENT SYSTEM USING IoT


By

B.M RAKIB HASAN - 12321065

A.M.M. GOLAM YEAZDANI-13101215

LABIB MD ISTIAQUE - 16141003

RAFEE MIZAN KHAN CHOWDHURY-16341020

Supervised by:

Dr. AMITABHA CHAKRABARTY

Assistant Professor

Department of Computer Science & Engineering

BRAC UNIVERSITY


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# ABSTRACT

With the increasing population and industrialization of nations throughout the globe, waste has become a great concern for all of us. Over years, researchers figured that only waste management is not enough for its proper treatment and disposal techniques to preserve our environment and keeping it clean in this era of globalization. With the help of technology researchers have, introduced IoT based Smart Waste Management solutions and initiatives that ensures reduced amount of time and energy required to provide waste management services and reduce the amount of waste generated. Unfortunately, developing countries are not being able to implement those existing solutions due to many factors like socio-economic environment. Therefore, in this research we have concentrated our thought on developing a smart IoT based waste management system for developing countries like Bangladesh that will ensure proper disposal, collection, transportation and recycling of household waste with the minimum amount of resources being available.

# ACKNOWLEDGEMENT AND DEDICATION

Numerous people have supported us during our research work. A few words' mention here cannot adequately capture all our appreciation.

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Finally, yet importantly, we would like to thank our parents, our brothers and sisters, for all their enduring support and always believing in us.

# AUTHORS' DECLARATION

We hereby declare that this thesis is a presentation of our original work. Materials of work found by other researchers are mentioned with due reference to the literature and acknowledgement of collaborative research and discussions.

This work done under the guidance of Dr. Amitabha Chakrabarty, at the Department of Computer Science and Engineering, BRAC University, Dhaka.

Date of Submission:08-July-2017

**SIGNATURE OF THE AUTHORS:**

………………………………………………

A.M.M. GOLAM YEAZDANI

13101215

………………………………………………

LABIB MD ISTIAQUE

16141003

………………………………………………

RAFEE MIZAN KHAN CHOWDHURY

16341020

………………………………………………

B.M RAKIB HASAN

12321065

**SIGNATURE OF SUPERVISOR:**

………………………………………………

DR. AMITABHA CHAKRABARTY

ASSISTANT PROFESSOR

DEPT. OF COMPUTER SCIENCE,

BRAC UNIVERSITY

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# CHAPTER-1

## 1. INTRODUCTION

Waste management is one of the core concerns of modern age. As nations around the world are developing, their concerns and accountability for a healthier and sustainable environment is also increasing. While developed countries are inventing and implementing smart solutions for waste management and bringing about huge positive impacts, waste management seems to be a play out of the league for the under developed or developing countries. There are numerous categories and each with different classifications of waste materials, like clinical to nuclear, biodegradable to non-bio-degradable and common household to industrial toxic waste. While developed countries are able to manage and treat these waste materials of different categories, developing countries like India and Bangladesh are still struggling with the collections and proper disposal of common household waste materials. Disorganized management and dumping of waste is a noticeable cause for ruining the environment in the major cities of these developing countries. Currently, according to a UNFPA report, Dhaka is one of the most polluted cities in the world and one of the issues concerned is the management of municipal waste. Implementing existing smart solutions for waste management systems in developing countries like Bangladesh is a far greater challenge due to many different factors e.g.: socio-economic environment, and the unplanned infrastructural issues. Waste are carried and thrown improperly leading to unhealthy and inhabitable environment that costs the government insane amount of money with not at all positive impact. Therefore, wastes and garbage need to be packed, dumped, collected, transported, manipulated and recycled properly in such ways that garbage becomes a precious wealth of the country.

In this research, we proposed to design and implement an effective smart waste management system based on IoT in perspective of developing countries like Bangladesh, using Linear

Regression algorithme for smart decision making systems and Decreasing Time algorithm for collection and sorting of waste.

## 1.1 Motivation

Smart Waste Management Systems based on IoT is one of the core component of modern age hype Smart City. There are countless Smart IoT based Solutions for waste management systems which are being implemented throughout the globe, in the developed and first world countries to be specific. However, Waste management is also a great problem in poor developing countries as waste is scattered all over roads due to improper methods of collection and dumping thus polluting the environment. Due to lot of factors including socio-economic and cultural drawbacks existing smart solutions are not compatible in developing countries like Bangladesh, as there exists basic problems regarding the primary task of waste management like proper disposal, collection, sorting, recycling etc.

In our thesis we are proposing Linear Regression Algorithm and Decreased Time Algorithm for predictive analysis of waste accumulation on day to day basis so as to ensure effective and efficient collection and sorting of disposed household waste materials accordingly. (The implementations and comparisons of before and after applying these algorithms are discussed and elaborated later in this paper).

## 1.2 Thesis Contribution

The thesis proposes a Smart Waste management system in relevance to developing country like Bangladesh. In last two decades there have been numerous initiatives taken with the help of foreign aids and support but they have failed to achieve results which can be said to be satisfactory and on acceptable level. This research aims to aid in achieving significant results for proper collection and disposal of household waste thus leading to a cleaner environment.

### 1.2.1 Problem Statement

The greatest problem regarding waste management in developing countries begins at the very starting point of the process. Due to lack of proper systems for disposal and collections, wastes and garbage's end up in the roads and surrounding. According to a report Zurburg 2002, the amount of waste generation in 2010 was around 20,000 tons per day, and it is estimated that by 2025 the amount will be no less than around 47000 tons per day. With the existing methods of collecting and disposal it is near impossible to manage such amount of waste in the future as around 30% of waste end up on the roads and public places due to ineffective disposing and collecting methods. Not only that, there is even no systematic methodology for the collected garbage for treating and recycling thus most of them end up in landfilling and river water, making the environment unhealthier. The prime impediment of implementing smart waste management system based on IoT in a developing country is the social and economic infrastructure of the country itself. The initial stage of this system comprises of proper disposal and collection, which is the biggest challenge. In addition, to motivate and influence people to follow proper waste disposal methods is also important.

### 1.2.2 Solutions

Previously there were numerous initiatives on waste management and educating people to dispose waste properly, and as they failed to achieve significant results, we have figured out the scopes that could be develop. To solve this problem, we have designed a process that ensures proper disposal and efficient waste collection. The procedures we designed involves creative initiative that will inspire people to dump in designated area or bins, and innovative method by using Decreasing Time algorithm or DTA for monitoring garbage generation and collection of the garbage's.

# CHAPTER-2

## 2. LITERATURE REVIEW

In this chapter we have discussed about all the main sequences of our model along with the background study and related works.

## 2.1 Related Works

Several papers on waste management of Bangladesh like journals and research papers have been published previously such as "Solid Waste Management System in Dhaka City of Bangladesh", "Waste Management in Bangladesh: Current Situations Suggestions for Action", "A CASE STUDY ON SOLID WASTE MANAGEMENT IN DHAKA CITY", "Municipal solid waste (MSW) management in Dhaka City, Bangladesh" etc. It has been seen that no other paper on our topic is there. In every paper, previous waste management of Bangladeshi is discussed or statistics are shown but no accurate solutions are given using algorithms. In this case, this paper would be a strong evidence along with solution as well on Smart Waste Management System of Bangladesh.

## 2.2 Background Study

The crucial part of our topic was to implement the whole process with the help of machine learning algorithms after collecting yearly data of waste of Bangladesh. To select the appropriate algorithm for our topic, we went through all the popular and effective machine learning algorithms in order to evolve our paper.

Commonly used algorithms are:

Linear Regression

Logistic Regression

Decision Tree

SVM

Naive Bayes

KNN

K-Means

Random Forest

Dimensionality Reduction Algorithms

Gradient Boost & Adaboost

Among above Machine Learning Algorithms, we have used Linear Regression very strongly. On the other hand, for time scheduling, Decreasing-Time Algorithm (DTA) has been used. Both algorithms are described with example to let know the basic idea of how algorithms work.

### 2.2.1 Linear Regression

It is utilized to estimate real values (cost of houses, number of calls, add up to deals and so on.) in light of ceaseless variable(s). Here, we set up connection among autonomous and subordinate factors by fitting a best line. This best fit line is known as regression line and represented by a linear equation Y= a *X + b.

The most ideal approach to comprehend straight relapse is to remember this experience of youth. Give us a chance to state, you ask a kid in fifth grade to mastermind individuals in his class by expanding request of weight, without asking them their weights! What do you think the youngster will do? He/she would likely look (outwardly investigate) at the tallness and work of individuals and orchestrate them utilizing a blend of these noticeable parameters. This is straight relapse, in actuality! The tyke has really made sense of that stature and manufacture would be corresponded to the weight by a relationship, which resembles the condition above.

In this equation:

Y – Dependent Variable

a – Slope

X – Independent variable

b – Intercept

These coefficients a and b are derived based on minimizing the sum of squared difference of distance between data points and regression line.

Looking at the below example. Here we have identified the best fit line having linear equation **y=0.2811x+13.9**. Now using this equation, we can find the weight, knowing the height of a person.

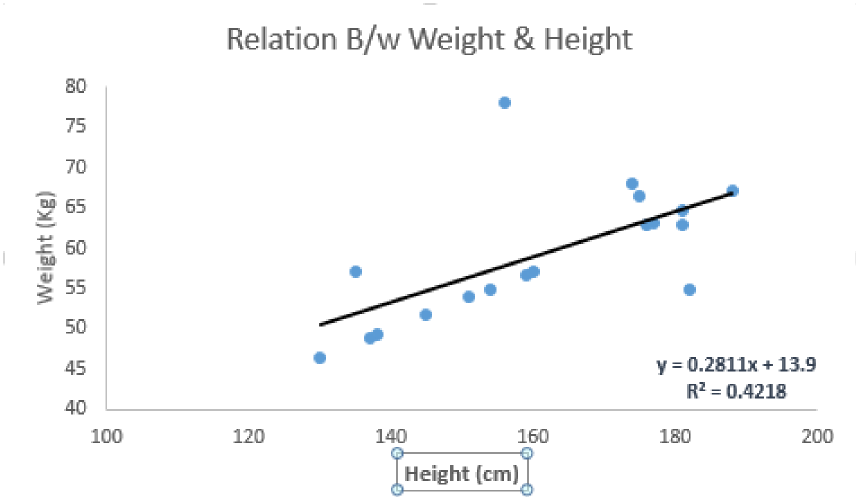


Fig: 01

Linear Regression is of for the most part two types: Simple Linear Regression and Multiple Linear Regression. Straightforward Linear Regression is portrayed by one free factor. What's more, Multiple Linear Regression (as the name proposes) is portrayed by different (more than 1) free variables. While discovering best fit line, you can fit a polynomial or curvilinear relapse. Also, these are known as polynomial or curvilinear relapse.

## 2.2.2 Decreasing-Time Algorithm

In Decreasing-Time Algorithm (DTA), longer jobs are done first and shorter jobs are saved for last. DTA creates a Priority List by listing the tasks in decreasing order of processing times (longest task first, shortest task last). Tasks with equal processing times can be listed in any order.

***Priority list is also called Decreasing-time List***

For example, given the project diagraph below,

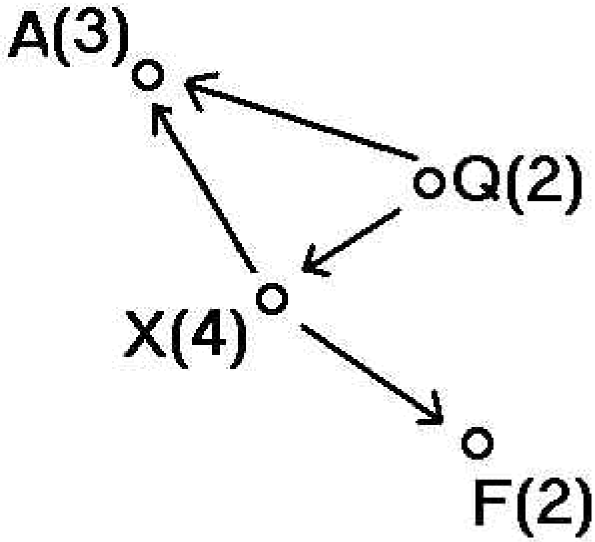


Fig: 02

The Priority List using the Decreasing-Time Algorithm (the so-called decreasing-time list) is *X A F Q R* (or *X A Q F R*).

*Precedence relations always override the Priority List when there is a conflict between the two.* ***Here, task X cannot actually be assigned first even though it is first on the Priority List since precedence relations demand that task Q precede task X.***

**A Problem with the Decreasing-Time Algorithm**

Although the strategy of scheduling the longer tasks first sounds good, it does have a major flaw. The DTA ignores any information in the project digraph that might indicate that one or more tasks should be done early rather than late. For instance, if one or more tasks with long processing times can't begin until task X (with a very short processing time) is finished, then assigning task X early will probably result in a shorter finishing time even though assigning task X early violates the DTA.

For example, suppose a project consists of five tasks: Y(6), Q(4), R(3), D(2), X(1) and the only precedence relation is $X \to Y$.

Using the Decreasing-Time Algorithm, the Priority List is **Y Q R D X**.

Now suppose there are two processors $P_1$ and $P_2$. Task Y is the longest task but cannot be assigned yet since $X \to Y$.

So, let's assign the next longest task, Q, to processor $P_1$ and the next longest task, R to $P_2$.

At hour 3, processor 2 completes task R and is ready again and is assigned task D.

At hour 4, processor 1 completes task Q and is ready again and is assigned task X.

At hour 5, both processors are ready again and task Y can be assigned to processor 1.

At hour 11, task Y is completed for a total project time of 11 hours.

(See the diagram below.)

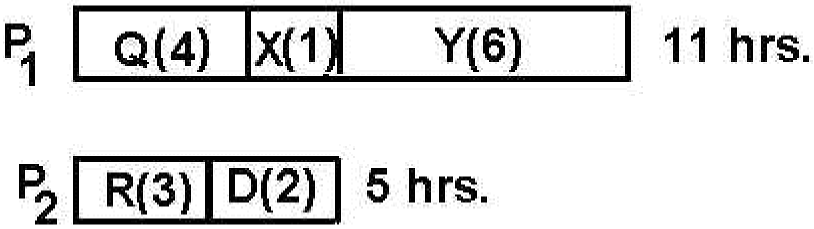


Fig: 03

But looks what happens if we temporarily ignore the DTA and go ahead and assign task X to $P_1$ in the beginning.

We still can't assign task Y (since task X is not done) but we can assign task Q to $P_2$.

At hour 1, processor 1 completes task X and is ready again and can now be assigned task Y.

At hour 4, processor 2 completes task Q and is ready again and is assigned task R.

At hour 7, processors 1 and 2 both complete their tasks and are ready again and $P_1$ is assigned task D.

At hour 9, processor 1 completes task D for a total project time of 9 hours.

(See the diagram below.)

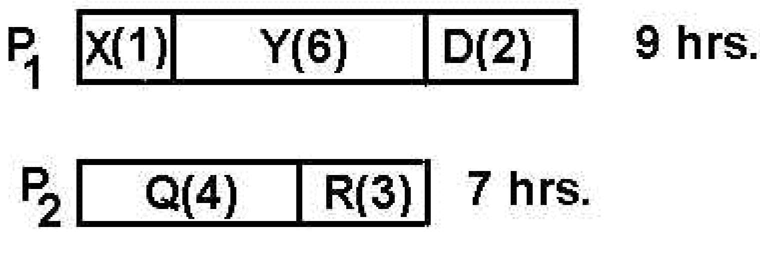


Fig: 04

As we can see, we were able to improve the project finishing time by violating the Decreasing-Time Algorithm.

## 2.3 Bio Degradable Oxy Bags

The first essential step to manage waste is packing garbage properly with bags so that it becomes easier to carry for further process. In that case, bio degradable oxy bags for household consumers would be the effective choice for packing garbage. Biodegradable bags that are fit for being deteriorated by bacteria or other living organisms.

Household consumers will pack waste with biodegradable bags and bags will be picked by the volunteers on right time. This packing system will make everything flexible for management as no stench will spread and waste will remain in ordered form.

## 2.4 Using of Smart Bins

In this management system, smart bins will play the vital role to start the processing in an organized way. There will be several bins in areas under one large regional office. Sonar sensor will be used in every bin to detect the level of waste. If the wastes cross a certain predetermined level of bin, it will notify employees to collect the waste.

Smart bins will also be able to determine the types of wastes. Virtual machines will be programmed to identify 3 types of wastes such as biodegradable, metal-plastic and glass. This differentiated information will later help Recycle Partners recycle the wastes. All information from bins will be saved in a .JSON file and sent to the Regional Office when a bin is full.

## 2.5 Smart Transport System

All wastes from smart bins will be collected by Regional Waste Collection Office. After collecting wastes, all information or data will be sent to Central Control Centre (CCC) in every 6 hours. Based on these data, CCC will assign trucks and employees. CCC will also have last 10 years data in its database to assign man power and transportation for every month as wastes amount depend on seasons. To predict the amount of waste and scheduling man-power, Machine Learning Algorithm (MLA) and Decreasing Time Algorithm (DTA) will be used successively.

## 2.5 Recycling Waste

Recycling is the process of converting waste materials into new materials and objects. If the recycling process is used properly on our waste, country will get benefited economically. Example can be given like based on the given data from Regional Office, Recycling Partners will differentiate and separate biodegrading, metal-plastic and glass from wastes. After separating wastes, they can send waste types to predetermined factories for further process or recovery. If waste type is metal and plastic, then above process can be used to recycle metal and plastic. For other types, digitalized recycling processes are now available to recycle waste.

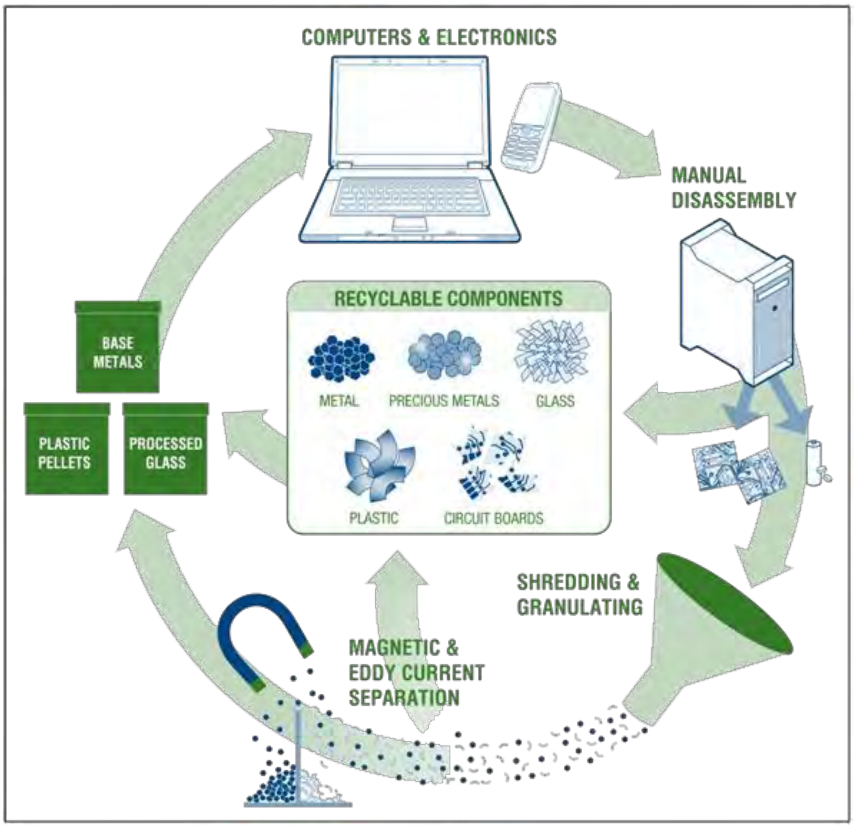


Fig: 05

# CHAPTER-3

## 3. RESEARCH DESIGN AND DATA COLLECTION

### 3.1 Study Area

In this part, we are mainly working on threee major areas of Dhaka city. Those areas are Mohakhali, Gulshan-1, Banani. Recently, the population are rapidly increasing, as a result, different types of wastes are getting produced at a very fast rate. Lack of financial resources, uneducated work force, inappropriate technology and lack of awareness of the community are the major problem to control waste management for the rapid growing area of Dhaka city.

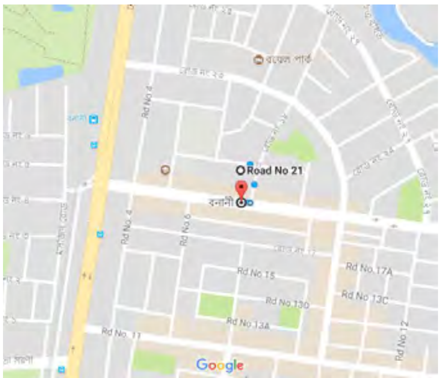


Fig: 06 ( Banani )

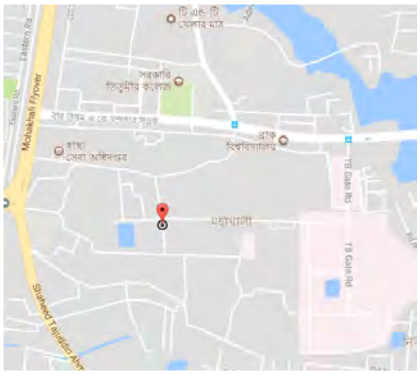

Fig: 07 ( Gulshan)

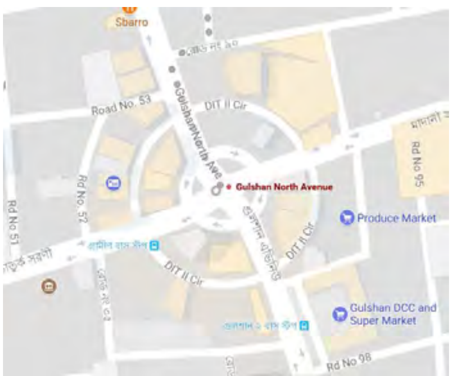


Fig: 08 (Mohakhali)

## 3.2 MSW Generation and Characteristics

Many factors depend on producing waste in city areas like geographical condition, climate conditions and waste collection system. For future waste management planning, we need quality and valuable wastes. Total MSW generation in DCC area is 4634.52 tons/day, with a per capital waste generation is 0.41kg/day (Concern, 2009). A percentage variation of the wastes given in Table 1

**Table 1: MSW composition (in %) at Dhaka between 1992 and 2005(Concern, 2009)**

| No | Parameter | 1992 In % | 2005 In % |
|---|---|---|---|
| 1 | Glass/Metal/Organic | 6.38 | 8.17 |
| 2 | Plastics | 1.74 | 4.1 |
| 3 | Textile | 1.83 | 4.57 |
| 4 | Paper/cardboard | 5.68 | 4.29 |
| 5 | Food waste | 84.37 | 78.87 |

From table, In Dhaka city MSW state that the highest percentage of waste is Metal/Organic food waste. Due to lack of consumption of raw foods this mainly happens. Moreover, fraction of organic waste decreased from 84% in year 1992 to 78% in year 2005. It reported in MSW that the existence of large organic fraction for many other developing countries such as India (40-60%) (Sharholy et al., 2008), Turkey (43%-64%) (Keser et al., 2012), China (57%-62%) (Chen et al., 2010), Nigeria (52%-65%), Nepal (60-70%) (Pokhrel and Viraraghavan, 2005).Physical and synthetic composition of MSW in Dhaka is exhibited in Fig. 4 and Fig. 5. As of late, level of plastics as bundling waste is changing because of huge scale process sustenance generation in Bangladesh. Additionally, fast food culture that spreads broadly all through the city is rolling out improvements in nourishment propensity and in addition the arrangement of waste things.

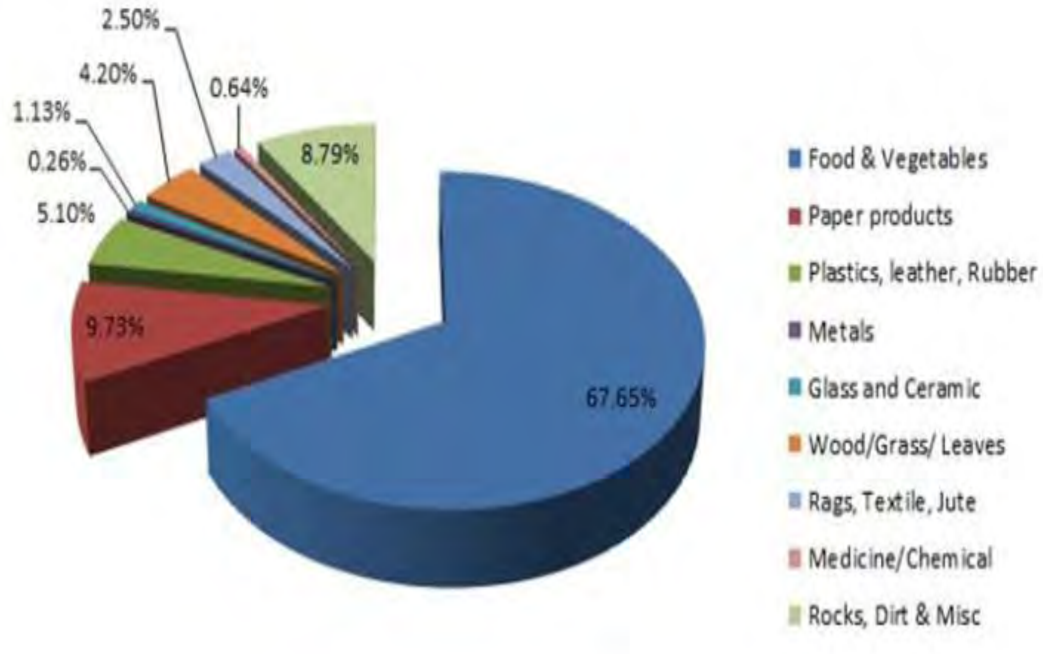


**Fig: 09 {Average Physical Composition of MSW in Dhaka (Concern, 2009)**

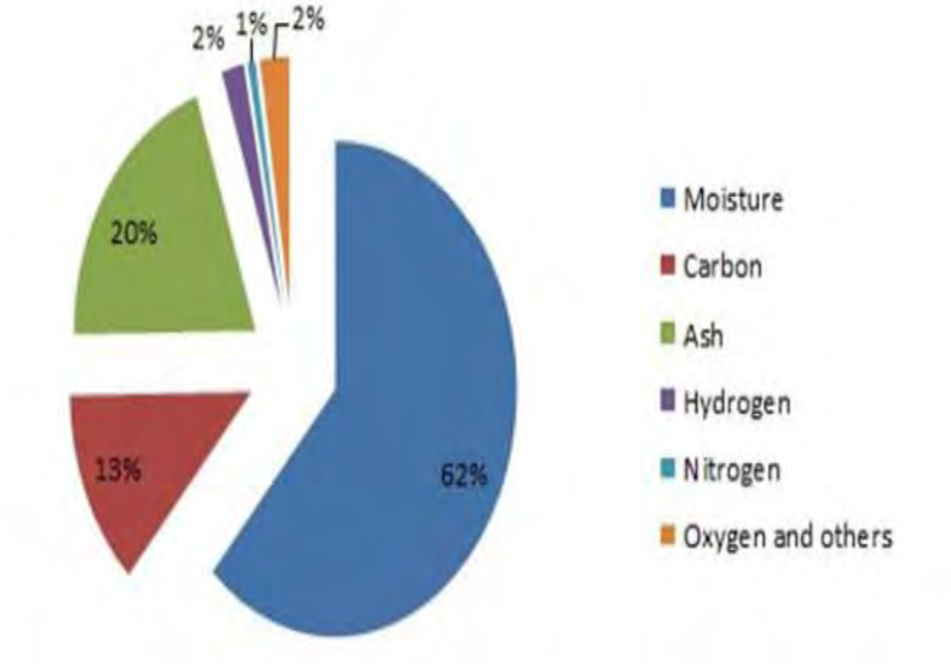


**Fig: 10 {Chemical composition in municipal solid waste in Dhaka city (Hamid Khan and Fayyaz Khan, 2009)}**

## 3.3 Waste Handling Processing in Dhaka City

The strategy of waste handling and processing has coordinate impact on general wellbeing, accumulation efficiency, asset recuperation of a MSWM framework (Talyan et al., 2008).Like other creating nations, however chaotic and casual, MSW in Dhaka generally directed and fixed by large informal sector. Executing source division conspire at source is a vital practice as a major aspect of maintainable MSW administration and arranging (Troschinetz and Mihelcic, 2009). However, there is no partition plot is right now accessible in Dhaka city**.** Indeed, tragically that there is no hazardous waste gathering and transfer plot is available in Dhaka city. Division of waste is a viable and manageable practice from the view purpose of asset recuperation as well as reuse of materials. Division of waste is a viable and manageable practice from the view purpose of asset recuperation as well as reuse of materials. Fig. 6. Demonstrates squander dealing with and preparing stream, regularly practiced in Dhaka.

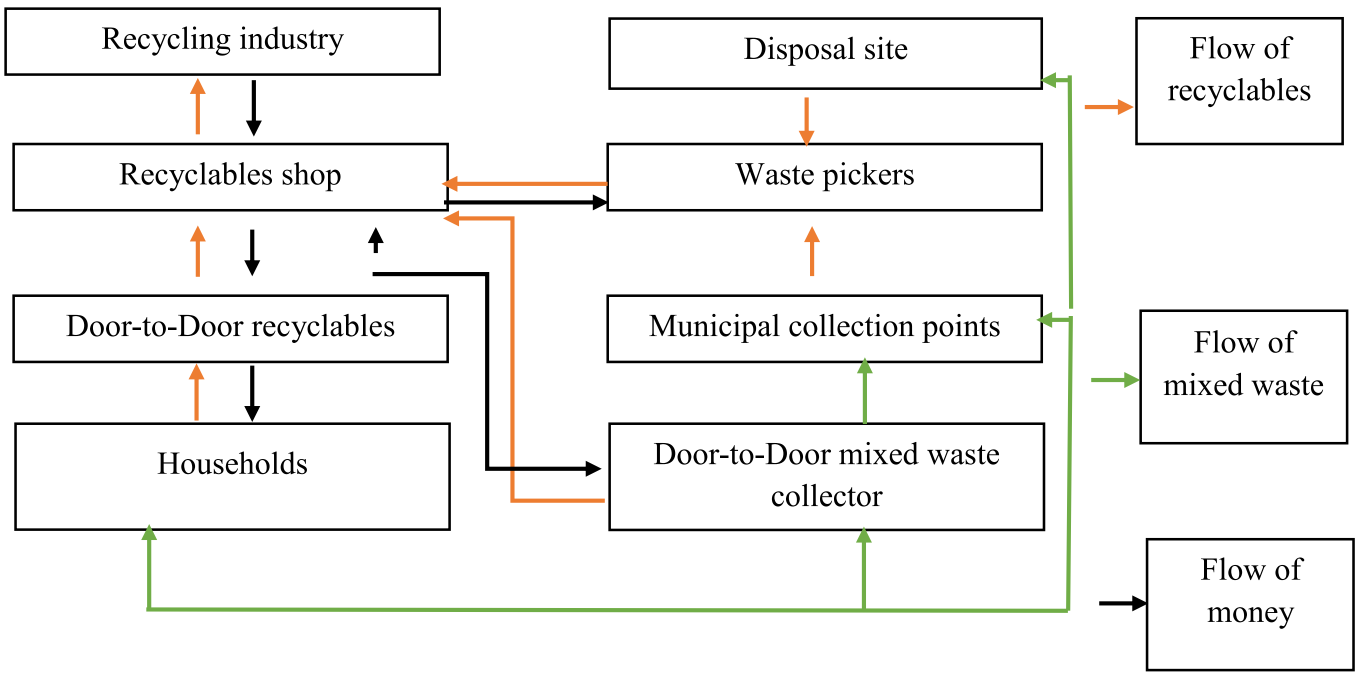


**Fig: 11 {Flow of waste, recyclables and money in MSW management in Dhaka (adopted from Matter et al. (2013))}**

## 3.4 Collection of Solid Waste

Dhaka City is presently seizing with the inconveniences of sky-scratching volumes of squanders. In that case, these inconveniences have likewise managed a window of prospects for city to discover arrangement. All sectors of people and the community have to use their new machinery also clearance Idea and rising awareness. A well-planned waste management system will help us to make atmosphere clear and budget friendly for peoples. Dhaka City Corporations are mainly maintaining this responsibility. DCC separated its area into 10 zones for supervision of solid waste production. Following table shows total waste composition in Dhaka city every day.

**Table 2: Nature of Waste composition in Bangladesh**

| Waste Composition | Bangladesh (Dhaka) (% By Weight) |
|---|---|
| Food and Vegetable | 70 |
| Paper Product | 4 |
| Plastics | 5 |
| Metals | 0.13 |
| Glass and Ceramics | 0.25 |
| Wood | 0.16 |
| Garden Waste | 1.1 |
| Other (Stone dirt etc) | 5 |
| Moisture | 65 |

Source: Ahmed, M.F., & Rahman, M.M,. 2000

Mainly three departments are control entire waste management. Those are conservancy, transport and mechanical engineering. Already number of surveys were carry out time to time by the World Bank, Bangladesh Centre for Advanced Studies (BCAS), Japan International Cooperation Agency and DCC itself for calculation of waste generation. For waste management in Dhaka city JICA also prepared “Clean Dhaka Master Plan”. Following table shows the growth rate of solid waste in Dhaka city from 1991 to 2025.The growth rate of waste is increasing dangerously

**Table 3: Growth in Solid Waste Generation in Urban Cities of Bangladesh**

| Year | Total population | Urban population(% Total) | Waste Generation rate(KG/cap/day) | Total Waste Generation(Tone/day) |
|---|---|---|---|---|
| 1991 | 20872204 | 20.15 | 0.49 | 9873.50 |
| 2001 | 28808477 | 23.39 | 0.50 | 11695.00 |
| 2004 | 32765152 | 25.08 | 0.50 | 16382.00 |
| 2025(estimated) | 78440000 | 40.00 | 0.60 | 47064.00 |

Source: ADBI and ADB 2000 &Zurbrugg 2002.

Department of DCC currently used 370 trucks and container carriers, 4,920 bin/container and 300 handcarts per day. In addition, 7,156 cleaners/ sweepers with 190 supervising officers and only 1 supervise transport officer for all events (DCC, 2004). Nearly 20% of wastes mention for repossession and recovering and more than 30% remains laying around on roadsides, open spaces or in drains (Dhaka city sate of environment: 2005: 1). World Bank claims that the waste generation of Dhaka Metropolitan area (360 sq. km) in 1998 was 3,944 tons/day (WB1998a in BCAS, 2003). JICA and DCC specialists was prepared a project name "Solid Waste Management Project" in 2000 and it displays that every day areas of Dhaka city generates 4,750 tons of solid wastes. Another report mention that the waste generation of DCC area was no less than 3,700 tons per day (Imtiaz and Alam, 2002). Some reports also claim that the waste generation of DCC is about 4,000 to 5,000 tons/day (The Daily Star, 21 June 2004). Similarly, JICA team of "Clean Dhaka Master Plan" found the existing solid waste generation (dry season) within Dhaka City Corporation area 3,340 tons/day, will increase to 4,600-5,100 tons/day in 2015 (JICA, 2004). The team also mentioned during the summer when fruits are available richly, the waste generation would be a little higher than regular time which may result in 3,500 tons of average waste generation.

## 3.5 Solid Waste Generation in Bangladesh

- 1995:10742 tons/day
- 2001:17000-tons/ day
- 2025:4.064 tons/day (estimated)

### 3.5.1 Solid Waste Generation Per Day

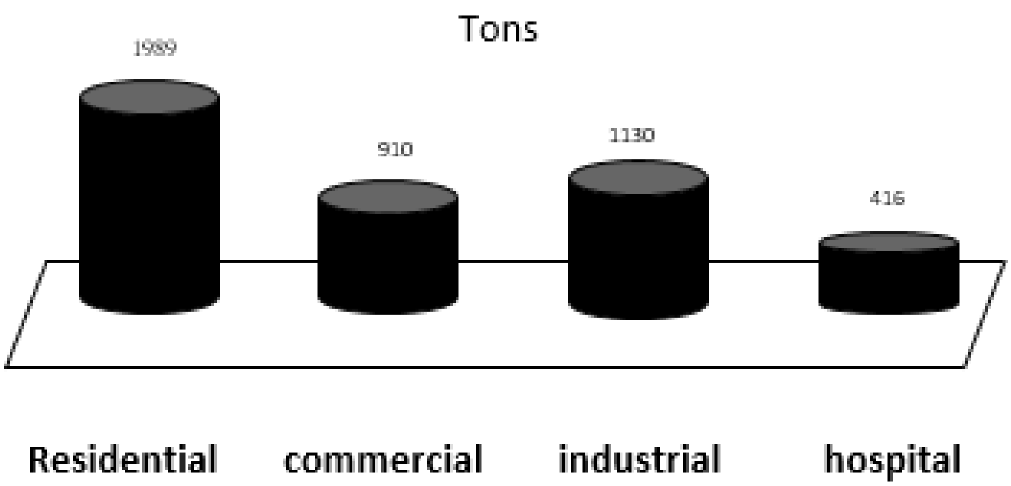


**Figure 12: Solid Waste Generation per Day in Tons**

## 3.6 Education Level of the Workers

Form several paper we collect some data where we find the level of educated workers. The education level of workers of the capital Dhaka City of Bangladesh is given in the Table: 4

**Table 4: Education Level of the Workers**

| **Education Level of the Workers** | **Percent (%)** |
|---|---|
| Uneducated | 45 |
| Primary school pass | 30 |
| Under SSC pass | 9 |
| SSC pass | 6 |
| HSC pass | 5 |
| HSC pass to Under graduate | 3 |
| Graduated | 2 |
| Total | 100 |

The above table showed that, the percentage of uneducated people was about 45% where encompasses mostly the rickshaw puller, day laborer and other percentage shows that people were educated in primary, SSC, HSC, Under graduate and graduate level.

We can understand the condition from the figure below:

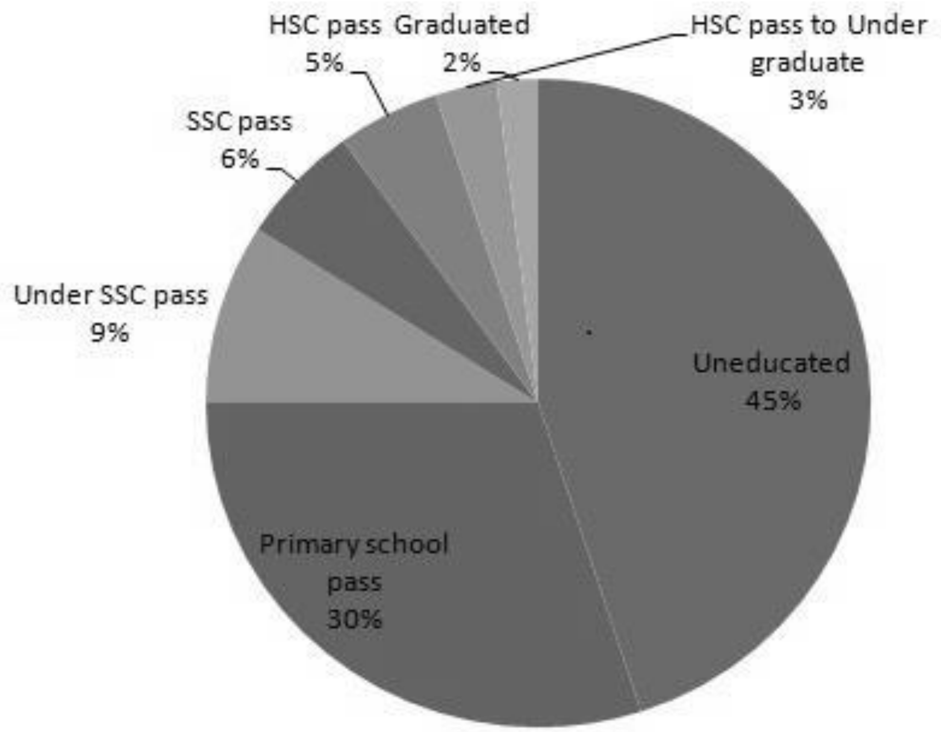


**Figure 13: Education Level of the Workers**

## 3.7 Possible Sources of Waste

There are several types of wastes that can be found in the environment. Let us discuss the possible sources of waste.

### 3.7.1 Commercial Sources

One of the biggest sources of waste production are commercial sources. It means different types of industries like garments, pharmaceuticals Company, hospital and other industry. Different industries using huge number of chimerical like sulfuric acid, chromium, ammonium sulfate, ammonium chloride, and calcium oxide. Those wastes may contain chromium salts and/or tannic acid. Insect killer and fungicide used by the manufactures. Some sort of heavy metals may produce in Metallic and non-metallic industries. Dust is also a source of pollution for soil, which is discharge from smelter from those industries. If dust is not disposed of appropriately, it will hamper our soil and agricultural fields.
Hospital and pharmaceutical industries produce three types of wastes-

- Infectious waste -(Pathological tissues, organs, body parts, blood and blood products, body fluids, placenta, human excreta, culture materials from laboratories and other infectious materials.)
- Sharp Waste(Needles, syringes, intravenous set, scalpel, saw, blades, broken glass, nails and sharps generated from support service, etc.)
- Non-infectious Waste (Expired drugs, waste contaminated with cytotoxic drugs and leftover cytotoxic drugs & radioactive waste)

### 3.7.2 Household Waste

Another big source of waste is Household waste. The percentage of Household waste is around 49.08% and about 1718tons per day. Many types of wastes gather in Household waste. Like vegetable peelings, onion seed coat, broken plastic and festal, spider etc. Soil and dust, pieces of thread, animal fasces, grasses, used shoes, pieces of cloth, small bottles, soot, used car parts, etc.

### 3.7.3 Hospital and Clinic Waste

In Dhaka city, there are more than 500 clinics and hospital. Everyday all those hospitals and clinics are generating vast amount of waste. The present average of medical waste generation in hospitals and clinics are calculated using 1kg/bed/day and an extra 200 kg/year. Around 20% of the whole waste (255 tons, 7.29 % of total solid waste generated per day) produced by hospitals in Dhaka city is dangerous and transferrable. Each bed provide small bowls or plastic bins used for gathering waste and emptied into larger containers. Wastes from operation theaters, laboratories, and kitchens dumped into these municipal bins. As hospital waste are more unsafe than other wastes because it contains toxic and infectious materials. All sorts of medical wastes like syringes and needles thrown into the municipal dustbin in Dhaka city. Therefore, inflectional diseases spread out easily.

### 3.7.4 Tanning Waste

Tanning waste is alternative type of industrial waste, which is also polluting then weather and environment dangerously. In Hazaribag area of Dhaka city, there are around 149 tanning industries and those industries producing 18,000 litres of liquid wastes and 115 tons of wastes. Several types of chemical used in tanning factories like sulfuric acid, chromium, ammonium sulfate, ammonium chloride, and calcium. The wastes of tanning factories have dangerous impact on atmosphere in terms of health, welfare, and environment like fever, headaches, respiratory and skin diseases and may bring unwanted changes in land use and fisheries. It has also negative impact on groundwater, surface water, and the ecosystem in general.

# CHAPTER-4

## 4. Methodology

In the proposed system, we are implementing algorithms to make the system smart and automatic. The existing system in the third world developing countries are not smart and automated at all. However, we are specially designing the whole system for the developing countries specially. The algorithms are mainly divided into two parts. One part is being used for sorting and priority analysis for the job assigning task of the system for the employees or freelancers who are going to work for the system. Another part is the machine learning part, where we are using the previous data of the location to predict how much the waste might be generated in the area on the exact time and how many workers or employees that the project office or the system needs on that exact time so that the system always prepared and there will be no shortage of employees.

## 4.1 Algorithm for Automatic Employee Work Assign

We are using Decreasing Time Algorithm (DTA) for sorting and priority analysis for the job assigning task of the system for the employees or freelancers who are going to work for the system. When wasted are being filled up in the smart bins which will be connected in the internet and equipped by sonar sensors, the data will be sent to regional office and then on the basis of waste amount the algorithm creates a priority table is created in which we will get the most time consuming as in the most filled up waste in the top and the least filled up waste as in the least time consuming task in the last. So, we have the task list in decreasing order.

So, the bin which is almost filled up will be treated first. Also if available, the system will assign more than one employee if needed to clear out an area with comperatively more waste filling up in the bins. Here, the highest amount of waste collection by an employee is also considered and if the amount is more than what an employee can carry, the algorithm will not count the priority table as 'done' and will assign another employee or freelancer there.

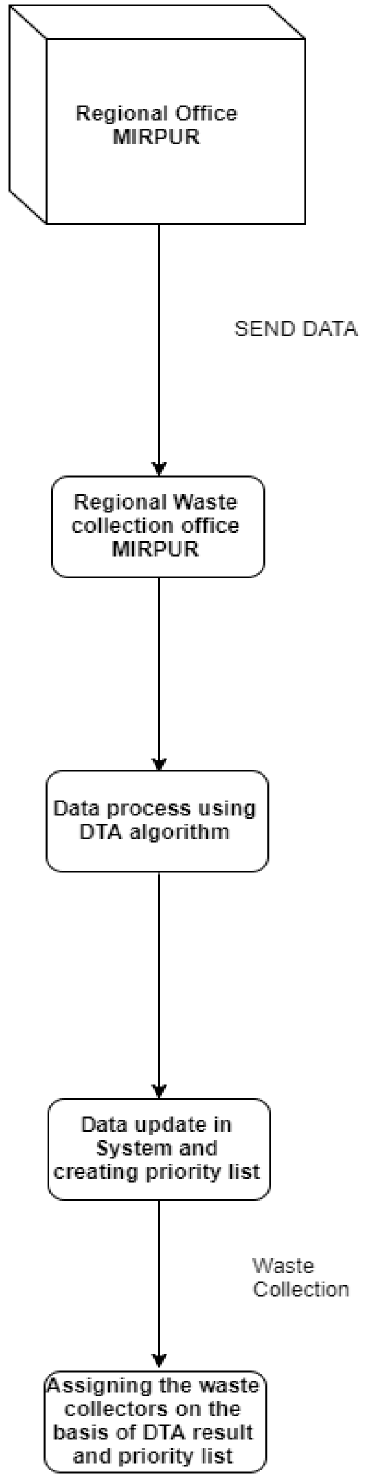


Fig:DTA for employee assign

## 4.2 Algorithm for Automatic Trucks/Collection Vehicle Assign

The same way mentioned above, we are also assigning trucks to collect treated wastes from the regional offices. The data will be sent to Central Control Centre (CCC) and then on the basis of waste amount the algorithm creates a priority table is created in which we will get the most time consuming as in the most filled up waste in the top and the least filled up waste as in the least time consuming task in the last. So, we have the task list in decreasing order. So, the Regional Site which is almost filled up will be treated first.

Trucks will do the same priority list and they will go to the regional office with most wastes waiting for them to collected first and then the least amount of wastes. Here, the highest amount of waste collection by a truck is also considered and if the amount is more than what a truck can carry, the algorithm will not count the priority table as 'done' and will assign another truck there.

## 4.3 Machine Learning Algorithms for Future Waste Prediction

The first algorithm that we had used was linear regression, which seeks to predict the high and low amount of wastes as a linear combination of the features. The features that were used from the data we have are:

1. Highest amount of waste from that specific area
2. Lowest amount of waste from that specific area
3. Highest amount of waste that an employee or worker can collect per hour
4. Highest working hour of an employee or worker
5. Highest amount of wastes that an employee or worker can collect per day (excluding transportation time, lunch, resting and other human system loss etc.)
6. Approximate system loss time

Therefore, for the $i^{th}$ pair of consecutive days, x *(i)* ∈ R^7 is a seven-dimensional feature vector, where we have x0 = 1 which is de-fined as the intercept term. There are 6 quantities to be predicted for each week of 7 consecutive days. For next 7 days' calculation, let y *(i)* ∈ $R^{42}$ denote the seven-dimensional vector that contains these quantities for the $i^{-th}$ pair of consecutive days.

The prediction of y *(i)* given x *(i)* is hθ(x *(i)* ) = θ T x, where θ ∈ $R^{7\times42}$

The cost function that linear regression seeks to minimize is

$$J(\theta) = \frac{1}{2}\sum_{i=1}^{m} \|h_\theta(x^{(i)}) - y^{(i)}\|^2, .$$

Let's take this as eq(1). Where m is the number of training examples. Letting $X \in R^{m\times 7}$ be defined such that $X_{ij} = x_j^{(i)}$ and $Y \in R^{m\times 42}$ be defined such that $Y_{ij} = y_j^{(i)}$, the value of θ that minimizes the cost in equation 1 is

$$\theta = (X^T X)^{-1} X^T Y.$$

The second algorithm that was used was a variation of functional regression, which searches for historical waste amount patterns that are most similar to the current waste amount patterns, then predicts the waste amount based upon these historical patterns. Given a sequence of nine consecutive days, define its spectrum f as follows. Let f(1), f(2) $\in R^5$ be the feature vectors for the first day and the second day, respectively. For *i* in the range 3 to 9, let f(i) $\in R^7$ be a vector containing the 7 points we are searching to predict for the $i$-th day in the sequence. Then define a metric on the space of spectra,

$$d(f_1, f_2) = \sum_{j=1}^{2} \Big[ w_1 \mathbf{1}[f_1(j)_1 \neq f_2(j)_1] + \sum_{k=2}^{5} w_k \big(f_1(j)_k - f_2(j)_k\big)^2 \Big],$$

where w is a weight vector that assigns weights to each feature. Since the first feature is the waste amount classification and the difference between classifications is meaningless, the squared difference has been replaced by an indicator function of whether the classifications are different.

Define a kernel,

$$\ker(t) = \max\{1 - t, 0\},$$

and let $neigh_k(f)$ denote the k indices $i \in \{1, \ldots, m\}$ of the k spectra in the training set that are the closest to f with respect to the metric d.

That is,

$$d(f^{(i)}, f) < d(f^{(j)}, f)$$

for all $i \in neigh_k(f)$ and $j \notin neigh_k(f)$, and $|neigh_k(f)| = k$.

Furthermore, define

$$h = \max_{i \in \{1,\ldots,m\}} d(f^{(i)}, f).$$

Then, given the values f (1), f (2) of the first two days of a spectrum f, the remainder of the spectrum f(i) for i in the range 3 to 9 can be predicted as,

$$\hat{f}(i) = \frac{\sum_{j \in \mathrm{neigh}_k(f)} \mathrm{ker}(d(f^{(j)}, f)/h) f^{(j)}(i)}{\sum_{j \in \mathrm{neigh}_k(f)} \mathrm{ker}(d(f^{(j)}, f)/h)}.$$

The error of the estimator $\hat{f}$ is defined to be,

$$\mathrm{Error} = \sum_{i=3}^{9} \|\hat{f}(i) - f(i)\|^2.$$

A more useful error that will be used in lieu of this is the root mean square (rms) error, which is defined to be,

$$\text{Error}_{rms} = \sqrt{\sum_{i=3}^{9} \frac{\|\hat{f}(i) - f(i)\|^2}{14}},$$

and provides the standard deviation of the individual error terms.

# CHAPTER-5

## 5. EXPERIMENTAL RESULTS

As this is a thesis project and the whole proposed system cannot be build and implemented in real life a year in under graduation level, we have built a close environment with virtual machines which works as a smart bin itself generation controlled random number from a given scale. The scale represents the actual amount of garbage that a smart bin can take in. There will be a change in numbers as we compare the operation of our smart system and the traditional system that the developing countries have nowadays. The random values are parsed in the database through JSON files which have different information about different types of wastes.

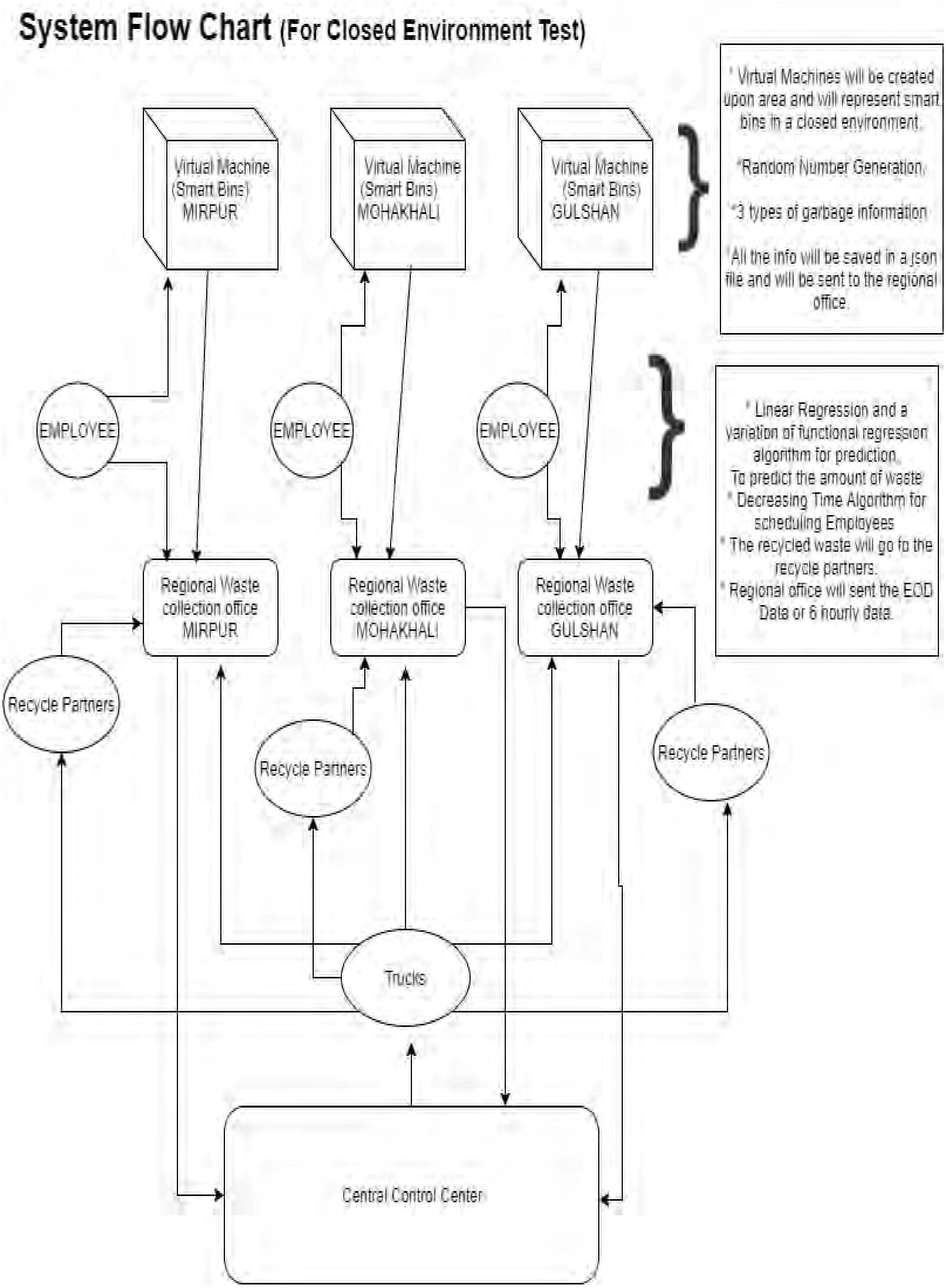
System Flow Chart (For Closed Environment Test)
Virtual Machine (Smart Bins) MIRPUR
Virtual Machine (Smart Bins) MOHAKHALI
Virtual Machine (Smart Bins) GULSHAN
* Virtual Machines will be created upon area and will represent smart bins in a closed environment.
*Random Number Generation.
*3 types of garbage information
*All the info will be saved in a json file and will be sent to the regional office.
EMPLOYEE
EMPLOYEE
EMPLOYEE
* Linear Regression and a variation of functional regression algorithm for prediction.
To predict the amount of waste
* Decreasing Time Algorithm for scheduling Employees
* The recycled waste will go to the recycle partners.
* Regional office will sent the EOD Data or 6 hourly data.
Regional Waste collection office MIRPUR
Regional Waste collection office MOHAKHALI
Regional Waste collection office GULSHAN
Recycle Partners
Recycle Partners
Recycle Partners
Trucks
Central Control Center

**Fig: 14**

In our close environment, we have tested the results and the results are like this:

We started with 150 units of waste. The wastes are for example in 5 different places. Each has wastes like following:


**Fig: 15**

We are also assuming that 1 worker or employee can work to collect 5 units of wastes / hour and he works 8 hours in total including lunch and human system loss.

So, we are taking inputs from 9 am to 6 pm for close environment. As we will have freelancing employment, we will have more workers who will work full time/ part time etc. we have taken results after every 3 hours. So, one result is at 9 am. 2nd result is at 12pm, 3rd result is at 3pm and 4th result is at 6pm.

Now, let us compare the data of our smart waste management system with the traditional waste management system.

Smart System at 9am:

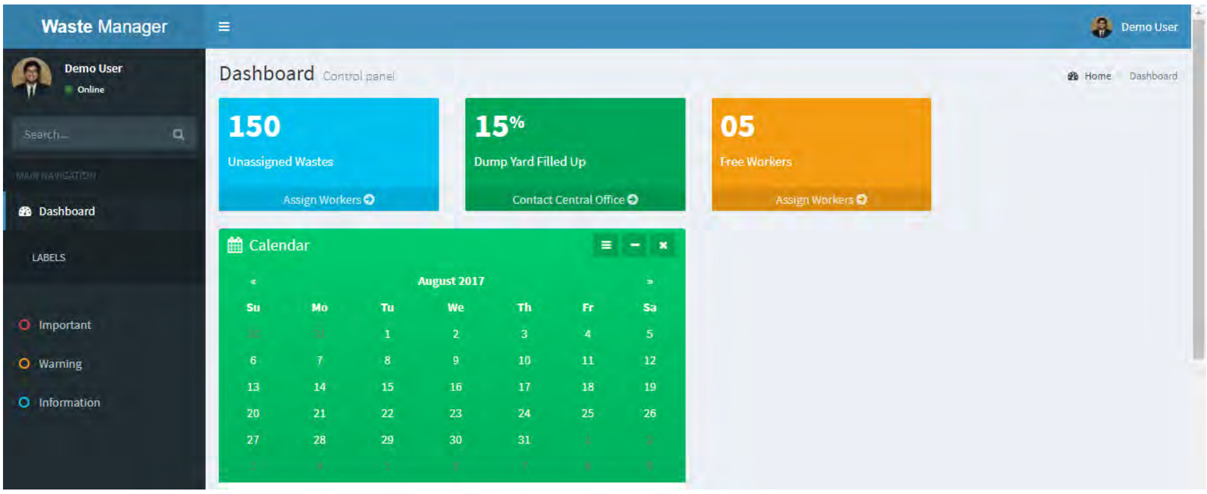


**Fig: 16**

Normal System at 9am:

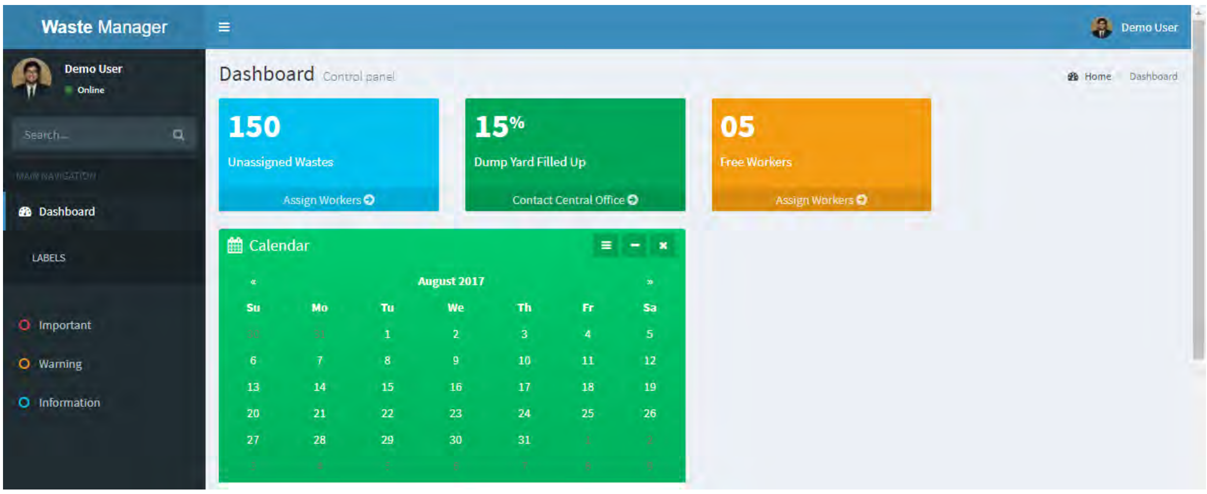


**Fig: 17**

Smart System at 12pm:

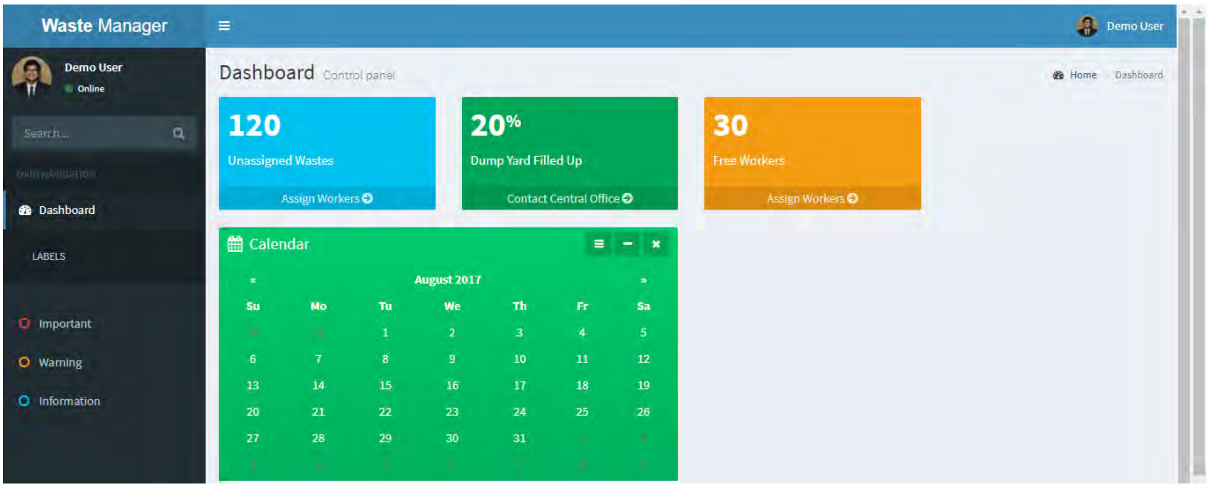


**Fig: 18**

Normal System at 12pm:

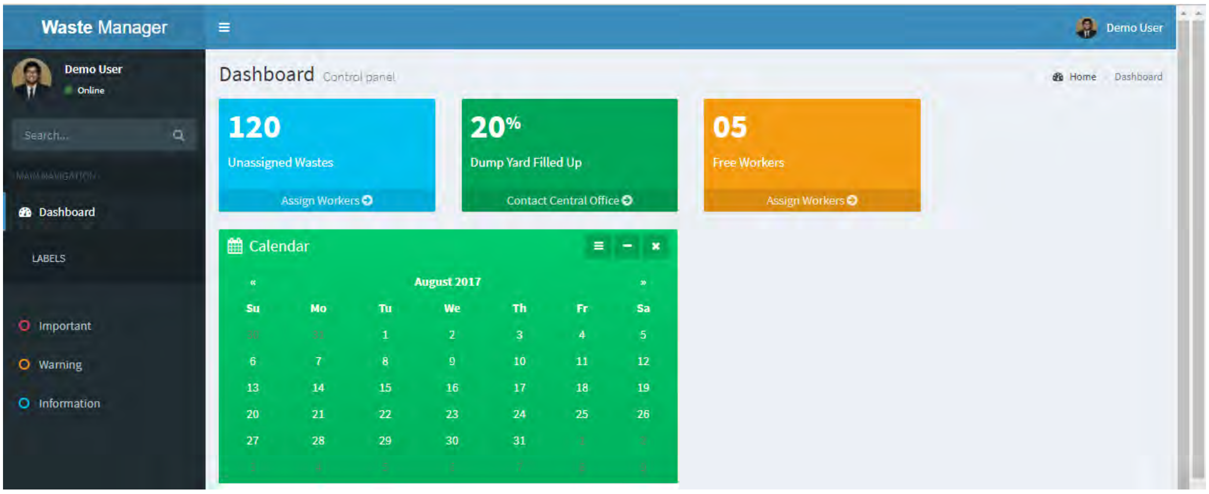


**Fig: 19**

Smart System at 3pm:

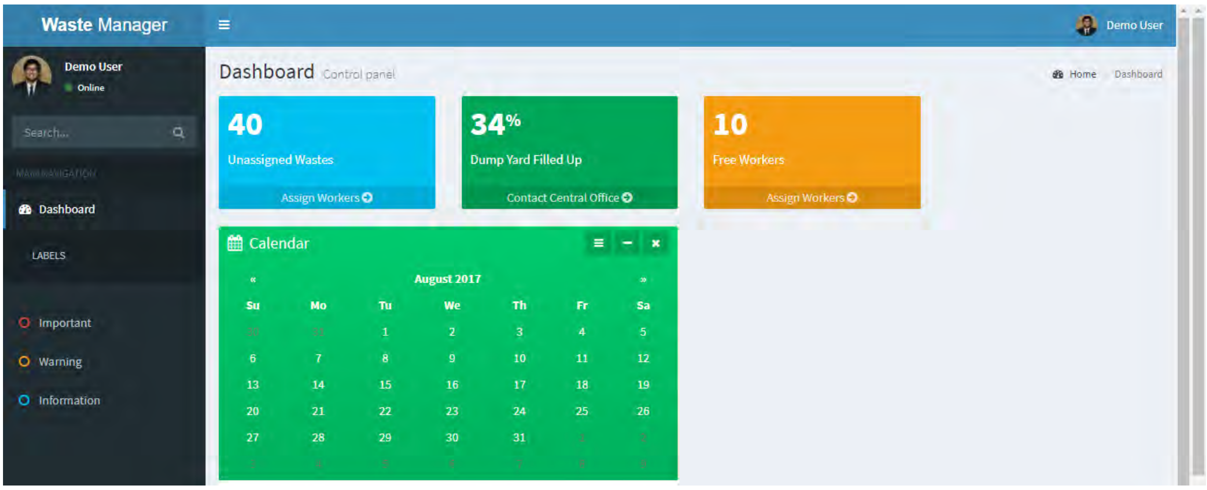


**Fig: 20**

Normal System at 3pm:

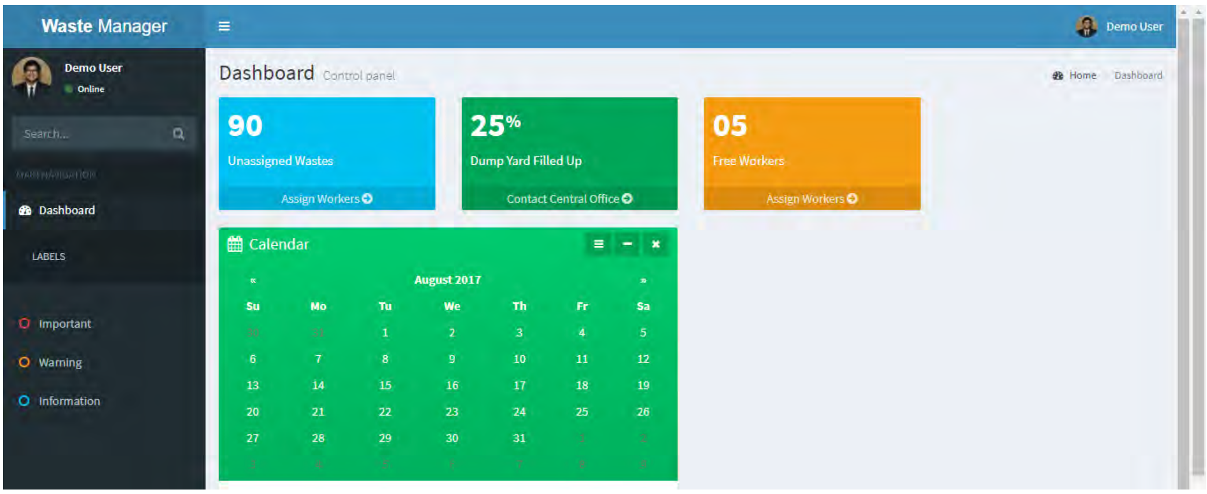


**Fig: 21**

Smart System at 6pm:

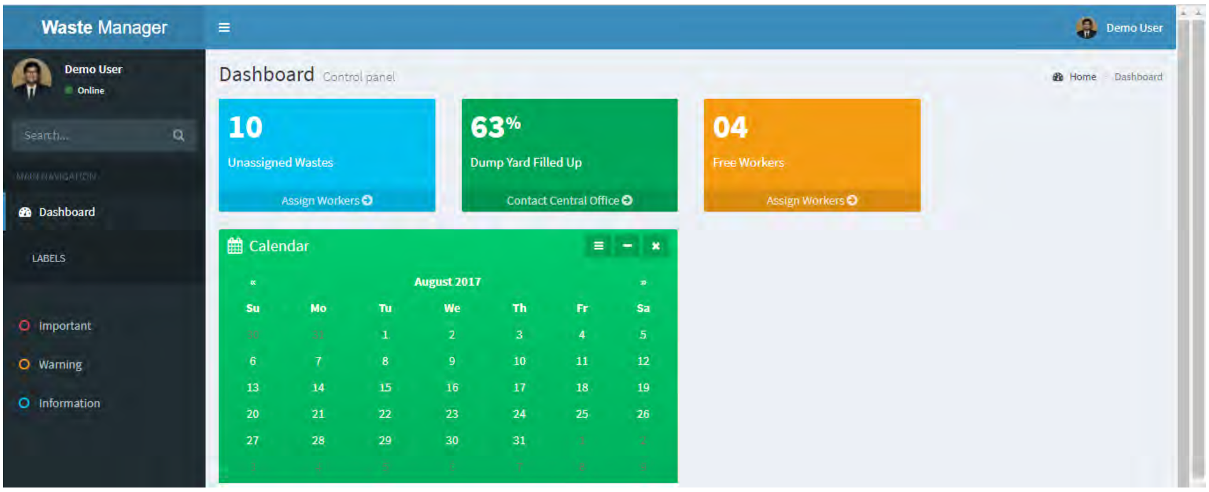


**Fig: 22**

Normal System at 6pm:

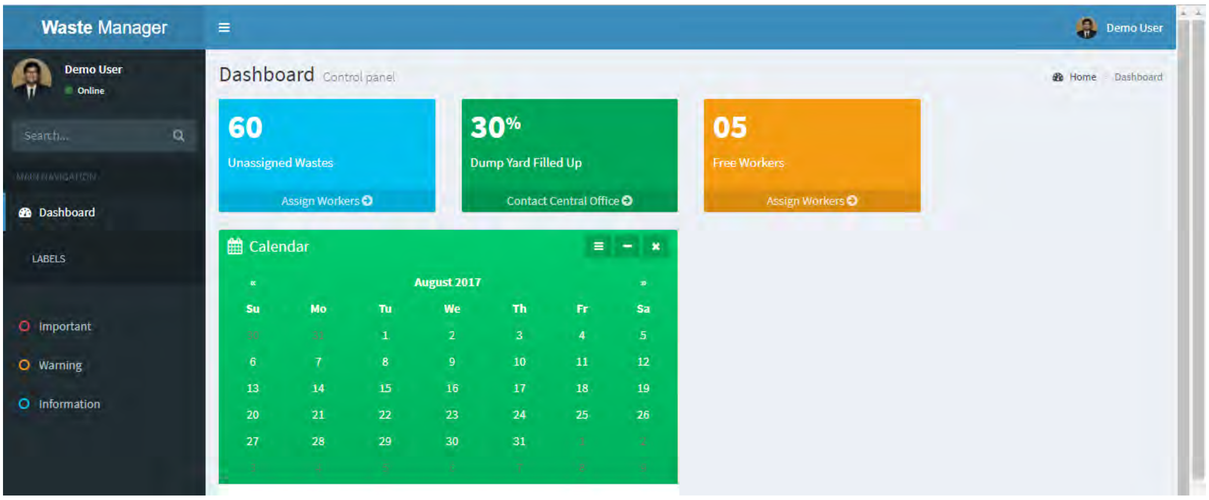


**Fig: 23**

So, we can see that our system works better in terms of collecting more wastes and using the workers or employees more effectively in comparison to the normal system that the developing countries use nowadays.

# CHAPTER-5

## 6. CONCLUSION AND FUTURE WORK

In this chapter, we have concluded this thesis report with a discussion of our thesis contribution as well as illustrated about our further work related to thesis.

### 6.1 Future Work

1. We are already in talks with the local cantonment authority where they are al- ready planning to impose our plan in Dhaka Cantonment as a pilot project. After this, within 3 years, we want to implement this in Gulshan, Baridhara, Banani, Bashundhara R/A, Uttara.

2. We will sell the compost waste to the fertilizer producers and also bio gas treat- mint plants. We also have plans to export some of the treated waste and earn foreign currency.

3. We also have plans to export some of the treated waste and earn foreign currency. So, this is our revenue generation policy for the social business.

4. We will also have educational facility for the people under 18 and the children of the people working for us. We are planning to merge with Jaago Foundation, BRAC NGO to be our education facility provider.

### 6.2 Conclusion

Population of Bangladesh is increasing day by day and waste is also generating at the same pace but the waste management system has not improved comparing to the waste production. As a result, environment is getting polluted due to unarranged and unevolved management system. Besides, utilization of waste is very improper whereas waste can be the precious wealth of a country.

Therefore, above smart waste management system using IoT can be very effective process in terms of manipulating waste for Dhaka City as well as other cities of Bangladesh. This model will digitalize and modernize the cities by applying IoT in waste management system of Bangladesh.

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