

UNIVERSITY OF BERGEN



A Web-based Solid Waste Management System for Sierra Leone

A thesis

presented to the

Faculty of Mathematics and Natural Science

at University of Bergen Norway

In Partial Fulfillment

of the Requirements

for the Degree of

Master of Science in Software Engineering

by

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September 2018

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Dedication

This thesis is dedicated to my parents Mummy Beatrice Sinnah Kamara and Late Papa Samuel Bassie Kamara, to my wife Beatrice Edwina Koroma for her unconditional love and support throughout my graduate study.

Preface

This project is a thesis at University of Bergen (Universitet i Bergen - UiB) as part of a master degree for the study program of Software Engineering. The project is done from end of 2017 to September 2018 and it is carried-out for Sierra Leone as a country which is experiencing serious waste problems. The author of this thesis is a Sierra Leonean who started his master's degree at UiB but chose to write his thesis in his home country Sierra Leone. On arriving in Sierra Leone after many years of living in Europe, he spotted the waste problem in his country as being very alarming and thought a thesis on it might be helpful in solving it. Fortunately, on submitting a proposal requesting to work on a master's topic related to waste management in Sierra Leone, the topic was approved. This is the way work on this thesis came about.

Sierra Leone, 2018-09-10

A handwritten signature in cursive script that reads "Kisimi Kayleemasa:-)".

Kisimi Kayleemasa

Abstract

The generation of waste is a continuous process as long as human activities are going on in the world. To address the threats that waste poses to life in general, it is important to manage waste properly. Waste management is the handling of solid refuse through the use of good waste management practices such as reuse, recycling and reduction. This research developed a web-based solid waste management system with the aim to promote a sustainable waste management system in Sierra Leone. The use of this developed system can help the local governments in Sierra Leone to track valuable information such as locations of collection sites; public waste bins; landfills; illegal dumping sites; trash collection schedules; and youth groups involving in waste management activities. By doing so, the local governments can ease their work in effectively managing waste to secure a clean environment in Sierra Leone. The system also stressed on promoting the slogan Trash is Money to encourage youth groups to launch business start-ups in the area of waste management. It thus has a feature for youth groups to register and manage their waste collection service clients. To practically make use of this feature, a youth group called eWomen Waste Management was launched as part of this thesis.

The system is a ASP.NET Web-based application and it was developed using the IDE Microsoft Visual Studio 2015 with C# as the programming language. Extensive Software packages or technologies used for the development of the application are MySQL, Microsoft SQL Server Management Studio 17, GITHUB and GIT.

Acknowledgment

Firstly, I would like to express my sincere gratitude to my advisors Prof. Uwe Egbert Wolter and Mr. Samson Hussien Gejibo (PhD) continuous support of my M.Sc. study and related research, for their patience, motivation, and immense knowledge. Their guidance helped me in all the time of research and writing of this thesis. I could not have imagined having better advisors and mentors for my M.Sc. study.

Besides my advisors, I would like to thank the rest of my thesis committee: Prof. Pål Ellingsen and Student Adviser Mr. Pål Magnus Gunnestad for their insightful comments and encouragement, but also for the hard question which incited me to widen my research from various perspectives.

My sincere thanks also go to Mr. Alfred Jatta Dumbuya, who provided me an opportunity to join their team as Monitoring and Evaluation Officer, and who gave access to the laboratory and research facilities. Without his precious support it would not be possible to conduct this research.

I thank my fellow team mates for the stimulating discussions, for the sleepless nights we were working together before deadlines, and for all the fun we have had during my two years of study. Also I thank my friends in the following Institutions - University of Bergen Norway and EBK University of Science and Technology Sierra Leone. In particular, I am grateful to Prof. Terje Kristensen of HiB Norway for enlightening me the first glance of research.

Last but not the least, I would like to thank my family: my wife Beatrice Edwina Koroma, my parents Mummy Beatrice Sinnah Kamara and Late Papa Samuel Bassie Kamara and to my brothers and sisters for supporting me spiritually throughout writing this thesis and my life in general.

K.K.K

Contents

Dedication	i
Preface	ii
Abstract	iii
Acknowledgment	iv
1 Introduction	3
1.1 Background	3
1.2 Study Area	4
1.2.1 Location	5
1.2.2 Area	6
1.2.3 Population	6
1.2.4 Climate and rainfall	6
1.2.5 Topography and soil	6
1.2.6 Existing land use	7
1.2.7 Problem Statement	7
1.2.8 Research purpose and objectives	8
1.2.9 Justification	10
1.2.10 Research Questions	10
1.2.11 Limitations	11
2 Literature review and theoretical framework	12
2.1 Terminologies and key concepts	12
2.1.1 Defining solid waste	12
2.1.2 Different types of waste	13

2.1.3	Defining a solid waste management system	15
2.2	Review of related literature	15
2.2.1	Solid waste situation in a developing country setting	15
3	Methodology	18
3.1	Data Collection	18
3.2	Youth Group in Solid Waste Management	18
3.3	Software Tools and Technologies	20
3.3.1	Visual Studio and C#	20
3.3.2	MySQL	21
4	Developing the web-based application	22
4.1	The Design Phase	22
5	Application Overview	30
5.1	High Level Overview	30
5.2	Implementation	31
5.2.1	Create Country, Region and Districts by System Admin	31
5.2.2	Some of the functions of the District Admin	33
6	Summary	39
6.1	Introduction	39
6.1.1	Current System	40
6.2	Conclusions	41
6.3	Status of the Prototype	42
6.4	Recommendations for Further Work	43
A	Additional Information	44
A.1	Extracts of some code	44
A.1.1	THIS IS CONTROLLER CODE FOR THE FRONT PAGE OF THE SYSTEM . . .	44
A.1.2	THIS IS THE CONTROLLER CODE FOR THE LOGIN FUNCTIONALITY . . .	49
A.1.3	THIS IS THE CONTROLLER CODE FOR THE MANAGE COUNTRY FUNC- TIONALITY	52

A.2 Acronyms and Glossary 56

 A.2.1 Acronyms 56

 A.2.2 Glossary 57

Bibliography **57**

List of Figures

1.1	The Map of Makeni City	5
1.2	Garbage pile right at the heart of Makeni City	9
3.1	Some of the door-to-door waste collectors of my youth group	19
3.2	A leisure club that was paved and beautified by a youth group	20
4.1	Relational Database Design	25
4.2	Use Case: Manage Countries	27
4.3	Use Case: Manage Accounts	28
4.4	Use Case: District Admin - Waste Management	29
4.5	Use Case: Youth Admin	29
5.1	High level view of the system.	30
5.2	The Login Interface	32
5.3	The Dash Board of the System Admin	32
5.4	The Add Country Functionality	33
5.5	The Add Region functionality	33
5.6	The Add District Functionality	34
5.7	The Update District Functionality	34
5.8	Create District Admin Account	35
5.9	Create Communities	35
5.10	Create Sections	36
5.11	Create Wards	36
5.12	Create Constituencies	37

5.13 Create Youth Group 38

Chapter 1

Introduction

1.1 Background

Sustainable development is key to the eradication of poverty from the world. Driven by the notion that no one should be left behind, the world agreed on the Sustainable Development Goals (SDGs) for all countries to work indefatigably to achieve them for their nations. Environmental protection is one of the most fundamental pillars of sustainable development. Governments, civil society and private sector are facing serious challenges in their efforts to protect the environment. This is due to the fact that continuous economic activities, rapid urbanization, population growth and rise of living standards have tremendously accelerated the generation of municipal solid waste (MSW). Solid waste management (SWM) often represents a significant proportion of the total recurrent municipal budget in cities of low and middle income countries. [Schübeler \(1996\)](#). Municipal Solid Waste Management (MSWM) is of paramount importance and waste management in general plays a crucial role in the economic and social development of a country. The UN Commission considers waste as one focus area to drive sustainable development.

A popular slogan in the world today is "Trash is Money". Apart from cutting costs of management and disposal, since waste collection, sorting and processing is in most cases labour intensive, it serves to employ a substantial number of people. It is revealed that in India, over one million people are employed in the waste sector [Gupta \(2001\)](#). Trash is money because MSW has great potentials to transform into other forms of resource and energy through proper treat-

ment. Besides, the world is now paying much attention on waste management because of the increasing challenges of climate change that is resulting from MSW. Waste has negative impacts on the environment. For example, land filling, waste incineration and decomposition generate substantial amounts of methane, which are potent emissions of contributing to global warming. These emissions can however be captured and used to generate electricity and waste is converted into energy resources thereby bringing numerous climate benefits. Apart from that, waste reuse and resource recovery can reduce the values of total waste and hence reduce the cost of waste management. This can create economic opportunities especially for the disadvantaged.

Solid waste management involves the handling of solid refuse at their sources through storage, collection, transportation, recovery and treatment processes to disposal. Solid waste is one of the main sources and causes of environmental pollution. Many lives are lost every year due to environmental related diseases such as diarrhea, cholera, malaria fever, typhoid fever, river blindness to name but few. Majority of the people in Sierra Leone still live in filthy environments that are infected by cockroaches, rats and mosquitoes. The air, which is an inevitable source of life is polluted with chemical, pathogens or offensive odour. Underground water and surface water are often polluted by seepage refuse dumps. All this is due to mankind activities. This paper concentrates on domestic refuse consisting of degradable food wastes, leaves, dead animals and non-degradable ones such as plastics, bottles, nylon, medical waste.

Giving a statistical analysis, Hoornweg Daniel explained that ten years ago, there were 2.9 billion urban residents who generated about 0.64 kg of municipal solid waste per person per day (0.68 billion tones per year) [Kamara \(2018\)](#). The lack of successful MSWM system in Sierra Leone and high youth unemployment rate inspired this paper to investigate and analyze the MSWM in a city of Sierra Leone called Makeni and to develop a web-based solid waste management system aimed at promoting the effective management of solid waste in Sierra Leone.

1.2 Study Area

Though the system to be developed is for the whole of Sierra Leone, the study was practically conducted in the Makeni City Municipality, one of the biggest municipalities in the Northern

Province, Sierra Leone.

Figure 1.1: The Map of Makeni City



The area was selected because:

1. Makeni is one of the biggest cities in Sierra Leone and the biggest in the northern part of Sierra Leone;
2. Solid waste management is emerging as a major problem in Makeni City.

1.2.1 Location

The study area lies in the northern part of Sierra Leone. It is located 8.89 latitude and -12.04 longitude and it is situated at elevation 93 meters above sea level. Makeni is the largest city in the Northern Province of Sierra Leone. The city is the capital of Bombali District, and is the economic center of the Northern Province. Makeni lies approximately 137 kilometers (85 miles) east of Freetown which is the Capital City of Sierra Leone.

1.2.2 Area

Makeni City municipality town covers an area of 16.8 km^2 , has 2 constituencies which are made up of 2 wards which are in turn made up of wards, sections and many communities. The city has around 15000 household units and we are currently seeing a rise in the number of hotels, guesthouses and restaurants. Other visible structures are vegetable markets, fish markets, meat markets and institutional holdings.

1.2.3 Population

Makeni is the third largest city in Sierra Leone by population. The city of Makeni had a population of 80,840 in the 2004 census and a 2013 estimate of 112,428 [Encyclopedia](#).

The rate of growth of population over the last four decades has been rapid as seen in the population trend of 2004 and 2013. The composition of people is diverse and the steady rise in population is attributed to immigration of people from nearby places.

1.2.4 Climate and rainfall

Makeni city falls under the northern region of Sierra Leone. Makeni has a tropical climate. There are significant rainfalls in most months of the year. The short drying time has little effect on the overall climate and there is a high level of humidity. The annual rainfall averages approximately 3027 mm. In Makeni, the average annual temperature is 26.9 °C [CLIMATE-DATA.ORG](#).

1.2.5 Topography and soil

The bedrock underlying the soils in Makeni Area belongs to granites and acid gneisses of Precambrian age. It is covered with a layer of about 10 to 20 feet (3 to 6 meters) of highly weathered, usually clayey kaolinitic and/or sandy materials with a high content of sesquioxides, which may be present as plinthite mottles, but mainly as gravel-size hardened plinthite glaebules, or sometimes as sheets of ironstone hard pan.

1.2.6 Existing land use

The town area is mainly used for housing, farming and commercial enterprises. Commercial activities are predominantly undertaken keeping in mind the farming industry, which is the main income source for the city people. Hotels, recreation facilities, markets and shopping centers dominate the city. (Source: Makeni City Council).

1.2.7 Problem Statement

With garbage piling, an avalanche of garbage can kill children; such accidents can be easily avoided, but lack of solid waste management planning can allow such accidents to happen and must have possibly occurred before. In absence of a proper waste management system, the waste accumulates around the town and heaps of garbage can be seen around the city. Here are the main problems that form the problem statement

- Solid waste collection points are inequitably distributed and inadequate.

Makeni Municipality is notorious for its failure to set up proper waste management measures and techniques resulting in delayed collection of wastes from residential areas and the swelling of the city's major dump site in Ward 111. Inhabitants have no confidence in the municipality as far as managing its waste is concerned.

- No separation of waste carried out

Annual total solid waste per capita is 248 kg, which if extrapolated to the whole population of Makeni this amounts to approximately 25,000 tons of waste generated annually. According to a household and commercial sector survey-2015, most solid waste is produced in form of organic waste (44%) and stones or construction debris (38%). There is presently no separation of waste carried out in the city, whether at household level or by businesses. All waste is deposited together, which by the nature of the types of waste generated, makes it either practically difficult or unsafe to engage in effective sorting and separation even after they are collected.

- Insufficient facilities for waste collection and disposal.

According to the local government of Makeni City, they are always in short of collection

trucks and the few that are available are always having mechanical problems. This makes it almost impossible to offer effective services for a city which is highly populated and the largest in the Northern region.

- Lack of sufficient dustbins

Several attempts have been made to install dustbins as experimentation but the end is always either not properly maintaining them or scrape metal dealers are reportedly accused of stealing them.

- Inappropriate distribution of available dump sites and existence of illegal ones

The main dump site is located in a residential area in Ward 111 and has been the subject of several inspections by the county health department due to its pathetic condition. Recently, one of the most popular TV station called AYV visited the pathetic dumping site to air its condition all over the world. The people where the dumping site is are so bitter and want it removed from their surroundings.

- Lack of knowledge to involve in waste management business

Waste is scattered all over Sierra Leone but the good news is, most of the waste that is produced in Sierra Leone is recyclable. The business opportunities in waste management in Sierra Leone are therefore many but unfortunately, they are still not tapped on. This is because the average Sierra Leone does not know that trash is money.

1.2.8 Research purpose and objectives

The purpose of this thesis was to examine the solid waste management status in Sierra Leone using Makeni City municipal, Northern Province, Sierra Leone, in order to develop a web-based solid waste management system for sustainable solid waste management in future.

Objectives

1. Main Objective

Development of a web-based solid waste management system that will be able to capture and display data related to municipal solid waste.

Figure 1.2: Garbage pile right at the heart of Makeni City



2. Specific Objectives

- create a database that will enable storage and management of data related to the Municipal's solid waste.
- To identify illegal dump sites in the town.
- To identify and locate where the problems are within the current solid waste management system.
- To establish whether the community is willing to participate and contribute towards solid waste management.
- To promote the slogan TRASH IS MONEY and encourage youth groups to launch business start-ups in the business of waste management.
- Optimization of waste collection routes. It entails planning cost efficient waste collection route for transportation of waste to the landfills. Existing location of the waste

bins and the street maps will provide the proximity of the bins to the waste collection service routes.

1.2.9 Justification

Poverty is still a serious problem in Sierra Leone. According to UNCHS (1996) one way of estimating the scale of poverty in urban centres is to base it on the number of people who live in poor quality houses or neighbourhoods that lack the basic infrastructure services such as SWM.

Efforts have been made to suggest several approaches in order to improve SWM in developing countries. Sierra Leone is way behind when it comes to the proper management of its waste. Although talks have been going on about the benefits of proper waste management both in terms of promoting public health and creating job opportunities for the marginalized, one can still sense the lack of system in addressing the waste problem in Sierra Leone.

Through Web-based Solid Waste Management System, this research will attempt to improve the solid waste management situation in urban areas, specifically Makeni Municipality. The research's model will involve the use of Microsoft Visual Studio IDE 2015 and C# SDK for building a ASP.NET MVC Web-based Solid Waste Application, database and MySQL Server as the basic data server.

The choice of Web-based Solid Waste Management System comes with several benefits in terms of policy and practice. It will encourage transparency by aiding community participation since the relevant information can be accessed by all authorized parties via the web. Another merit will be an improvement in the ease of managing of solid waste since the database system will be centralized.

1.2.10 Research Questions

In order to achieve the above objectives, the following questions should be answered;

- Has Sierra Leone got a web-based solid waste management system that can efficiently track data related to waste management?
- Are the existing waste bins, collection sites and landfills properly identified?

- Are there any dump sites singled out as illegal by the Municipality?
- How are the problems related to the solid waste management system?
- Who should take the role and responsibility to improve the MSWM?
- Are there any existing optimal routes to the waste collection and dumping points?
- Do the municipalities possess an efficient and effective waste management database system?

1.2.11 Limitations

- Limited resources such as finances could lower the quality of the expected results.
- The refusal by locals, government and NGO officials to conduct open questionnaires may result in insufficient information.
- Reluctance by local authorities and organizations to support the initiative could lower the substance in the final output.
- Insufficient research materials. These could be attributed to the fact that Sierra Leone is lagging behind in terms of technology.
- Time available to develop the prototype could lower the quality of the expected results.

Chapter 2

Literature review and theoretical framework

There is an interdependence of living organisms and their ecosystem. Efforts have been made to understand this interdependence. One thing that is evident is that, the interdependence of organisms and their ecosystem implies that all living organisms have an effect on the environment. However, the impact of humans on the environment is greater than that of any other species. Human are the champions in modifying nature so drastically to suit their purposes. This very nature of man to change/modify/transform nature according to their needs has led to pollution and an ultimate effect of environmental degradation.

Economic development, although it plays a very important role in modern society, has changed our consumption patterns to the point where we now generate more waste than we ever did.

2.1 Terminologies and key concepts

In this section, attempt is made to deliberate on the terminologies and key concepts that are relevant in this study. We will look into terms and concepts like solid waste, the different types of solid waste and solid waste management system.

2.1.1 Defining solid waste

Solid waste is an object the holder discards, intends to discard or is required to discard. The 'holder' can either be the producer of waste or be in possession of waste. Solid waste is broadly

comprised of non-hazardous domestic, commercial and industrial refuse including household organic waste, hospital and institutional garbage, street sweepings, and construction wastes.

Contrary to developed nations where the waste generated from different sectors are generally treated separately, separate treatment of waste materials generated from different sectors in developing nations are not treated separately. Bottom line is, waste in developing nations are not handled properly and improper handling and disposal of solid waste has multi-dimensional impact on human and environmental well-being. Improper dumping of solid waste can lead to

- Clogging of drains
- Floods in the plains
- Pollution of air, soil and water
- Contamination of surface and ground water supplies
- Landslides in the hilly areas during rainy reasons

Burning of waste is a common practice in developing nations. Improper incineration and burning of waste materials contributes significantly to pollution, greenhouse gases generated from the landfills pose threat to human as well as the environment. To clearly pinpoint the obstacles to a sustainable solid waste management system, the rest of this literature review largely focuses on the problems associated with solid waste management in a developing country setting.

2.1.2 Different types of waste

One might want to know about the different types of waste that do exist. World World Bank offered eight major classifications of solid waste generators [Griffin and Campbel \(2018\)](#) as shown below. All the first seven can be classified as municipal waste.

- **Residual - Single and Multifamily Dwellings**

Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires), and household hazardous waste

- **Industrial - Light and heavy manufacturing, construction sites, power and chemical plants**
Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, special waste
- **Commercial - Stores, hotels, restaurants, markets, office buildings**
Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes, e-wastes
- **Institutional - Schools, hospitals (non-medical waste), prisons, government buildings, airports**
Same as commercial
- **Construction and Demolition - New construction sites, road repair, renovation sites, demolition of buildings**
Wood, steel, concrete, dirt, bricks, tiles
- **Municipal Services - Street cleaning, landscaping, parks, beaches, other recreational areas, water and waste water treatment plants**
Street sweepings; landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas, sludge
- **Process - Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing**
Industrial process wastes, scrap materials, off-specification products, slag
- **Agricultural - Crops, orchards, vineyards, dairies, feedlots, farms**
Spoiled food wastes, agricultural wastes (e.g., rice husks, cotton stalks, coconut shells, coffee waste), hazardous wastes (e.g., pesticides)

In the above classification, medical waste is missing. This waste is got from hospitals, nursing homes and clinics. Infectious wastes (bandages, gloves, cultures, swabs, blood and body fluids), hazardous wastes (sharps, instruments, chemicals), radioactive waste from cancer therapies, pharmaceutical waste are all examples of medical waste.

2.1.3 Defining a solid waste management system

Leaving solid waste without proper management is detrimental to living organisms including mankind. Solid waste management is the process of managing waste through appropriate collection and treatment. Another aspect of solid waste management is the recycling of items that do not belong to trash. Waste management is therefore all about how solid waste can be transformed and used as a valuable resource.

Knowing what solid waste management is, a solid waste management system is a set of principles or procedures according to which waste is effectively managed.

2.2 Review of related literature

This section is the result of a search and evaluation of the available literature in this chosen topic area. It basically documents the state of the art with respect to the topic of this thesis.

2.2.1 Solid waste situation in a developing country setting

One of the most challenging problems facing any developing nation is solid waste management. The ever growing population followed by rapid urbanization produces a large amount of solid wastes. However, these nations are not empowered to deal with the problem of solid waste management. In addition to restricting revenue sources, if recyclables are not sorted it creates burden on waste collection by increasing waste volume and weight. This is exactly the case in Sierra Leone. It is recently that Sierra Leone is giving signals to encourage SMEs to involve in waste management. There is a tendency to focus only on waste collection. Therefore, focus on only the collection of solid waste and limited income generation strategies were among the challenges of incorporating SMEs in solid waste management [Tadesse et al. \(2008\)](#). In developed countries, local governments take care the function of managing their solid wastes. This is however not the case for the local governments of developing nations because they do not have the ability to provide even this basic function. In Sierra Leone, although the local countries are still with the mandate to manage the waste of their localities, waste management is under the purview of the Ministry of youth affairs with the hope that it will help to address the youth

unemployment problem. However, it is still not clear how the Ministry of Youth Affairs is doing.

Rapidly growing of population is one of the most severe problems that can be associated with solid waste management. Since people tend to move from rural areas to urban areas, this rapid increase in population consequently leads to increase in urban population. This increase in population does not match with the available finances and infrastructures. Solid waste management often represents a significant proportion of the total recurrent municipal budget in cities of low and middle income countries [Henry et al. \(2006\)](#). The public sector of developing countries appear to be inefficient and the continuous increase in cost has led governments to empower the youth to address the waste problem. The lack of finances is hence a very serious problem in developing countries. It leads to the lack of effective collection and transportation facilities. The infrastructure to support effective waste management is simply lacking. Waste disposal is therefore a big challenge. Illegal dumping sites are a norm of the society. People also resort to burning of waste in their areas. Even schools resort to the burning of waste in school campuses.

In terms of waste composition, there are significant differences between waste generated in developed countries and developing countries like Sierra Leone for example. The waste generated in developed countries are mainly inorganic in nature, whereas organic content form a large portion of waste in developing countries [Martin \(2002\)](#). This is consistent with the composition of waste in Sierra Leone. In Sierra Leone, organic waste comes first in terms of quantity then followed by plastic waste. In developing country scenario, the proportion of organic contents in waste is almost three times higher than that in developed countries [Olar \(2003\)](#).

There are so many environmental problems associated with waste and the impacts of solid waste on the environment is immense. The emission of Green House Gases (GHGs) is considered the most serious environmental problem in terms of waste. The waste management sector represents 4 percent of the total anthropogenic GHG emissions and landfills contribute the largest anthropogenic source of methane, contributing 90 percent to the total GHGs release from the waste sector in the United States [Weitz et al. \(2002\)](#).

Institutional problem is also a big issue in waste management. There are so many actors such as groups, individuals and organizations that are involved with waste as service users, service providers, intermediaries and/or regulators. The interests, agendas and roles of these actors

form a complicated web, which defines the prevalent waste management system in any developing nation [Sudhir et al. \(1997\)](#). As in the case of Sierra Leone also, the collection and disposal of refuse within an urban area has been traditionally perceived as the responsibility of the local municipal government (formal public sector). The provision of a waste management system by the local government is generally inadequate and ineffective. And people are generally still not fully aware that trash is money. This poor awareness and lack of knowledge caused lack of respect for MSEs and unwillingness to pay for the service. Most communities if not all are not aware of the advantages of SMEs' contribution in solid waste management. Therefore, there is still a preference for the use of the preexisting informal waste collection system over SMEs [Solomon \(2007\)](#).

Chapter 3

Methodology

The study was undertaken from late 2017 to September 2018. The study was developed to understand how a web-based solid waste management system can effectively promote the proper management of solid waste in Sierra Leone. It examined in depth the status of solid waste management in Sierra Leone and the opportunities one can derive from the proper management of waste through good waste management practices such as recycling, reduction and reuse. In order to gain knowledge of the system being studied, a business startup called eWomen Waste Management was launched. This business startup is engaged in door to door waste collection, plastic recycling, local production of trash bins (metal recycling or reuse) and making of briquettes and compost manure.

3.1 Data Collection

Data for the project was mainly collected through direct observation and semi-structured interviews with community groups, key informants and non-governmental organizations. Besides, I have reviewed reports and published information.

3.2 Youth Group in Solid Waste Management

To further understand the waste management status in Sierra Leone and most important to verify the notion that TRASH IS MONEY, I launched a business start-up called eWomen Waste

Management that is managed by a youth group.

Figure 3.1: Some of the door-to-door waste collectors of my youth group



With this youth group behind this waste management business start-up, authentic information was got to prove that waste management can be a lucrative business that can create job opportunities for the disadvantaged. This information is displayed in the web-based system for the public to consume. It is evident that the local governments are not capable of providing a sustainable solid waste management system. It is on this pretext that the previous government classified waste management under the Ministry of Youth. This research will emphasize on a model that will rely on the youth especially the disadvantaged to help solve the waste problem in a sustainable way. In the process, jobs will be created for the youth. With eWomen Waste Management, we succeeded in knowing that waste management can be a lucrative business because this youth group is currently involved in income generating activities within waste management with huge potential to get . These activities include the production of outdoor paving stones called eStones (eco-friendly stones), door to door waste collection, making of briquettes out of agricultural waste to discourage people from cutting trees to make charcoal, making compost out of greens (peels of fruit, vegetables etc.) and browns (dry leaves, egg cartons, paper towels etc). Since starch is needed to make briquettes, the youth group also embarks in making "gari" out of cassava. To advertise these activities further, this youth group is planning to launch "keke"

Figure 3.2: A leisure club that was paved and beautified by a youth group



taxis only to be operated by women and SolarFI hubs as kiosks to provide internet facilities, mobile phone charging and selling of attractive products. This web-based solid waste management system will capture all these selling points and make them known to the public. eWomen Waste Management also produces nice trash bins locally out of used drum metal and scrap wheels of hospital beds.

3.3 Software Tools and Technologies

This section presents details about the software tools and technologies used to develop the system.

3.3.1 Visual Studio and C#

Microsoft Visual Studio and C# were chosen to build the web-based waste management system for this thesis. Microsoft Visual Studio is an integrated development environment (IDE) from Microsoft. It can be used to develop console and graphical user interface applications along with Windows Forms applications, web sites, web applications, and web services in both native code together with managed code for all platforms supported by Microsoft Windows, Windows

Phone, .NET Framework, .NET Compact Framework and Microsoft Silver light. My choice of Microsoft Visual Studio is also based on the fact that it offered the option to develop a MVC (Model, View, Controller) web-application and MVC is a trend that allows you to create robust, reliable and flexible web applications. The MVC is a software architectural design for implementing user interfaces on computers. As a pattern, it is a great architecture no matter whatever the language you are using for the development.

C# is a modern object-oriented programming language developed in 2000 by Anders Hejlsberg at Microsoft as a rival to Java (which it is quite similar to). It was created because Sun, (later bought by Oracle) did not want Microsoft to make changes to java, so Microsoft chose to create their own language instead. C# has grown quickly since it was first created, with extensive support from Microsoft helping it to gain a large following; it is now one of the most popular programming languages in the world.

3.3.2 MySQL

Using a Relational Database Management System (RDBMS) to store data has so many advantages. Some advantages include easy manage, retrieval, update, better organization of data, greater flexibility in accessing and managing data, better security and data integrity. This web-based waste management system uses MySQL Relational Database Management System (RDBMS) as a backend to store data.

MySQL was originally founded and developed in Sweden by two Swedes and a Finn: David Axmark, Allan Larsson and Michael “Monty” Widenius, who had worked together since the 1980s. MySQL is an open source RDBMS. It is fast, reliable, popular and cost saving way of building databases for web applications.

MySQL is a popular choice of database for use in web applications and it has become the world's most popular open source database because of its high performance, high reliability and ease of use. MySQL runs on more than 20 platforms including Linux, Windows, Mac OS, Solaris, HP-UX and IBM AIX. MySQL also offers a comprehensive range of database tools, support, training and consulting services.

Chapter 4

Developing the web-based application

In this chapter, the development of a web-based application to promote solid waste management in Sierra Leone will be demonstrated using real code for a real project. It is in this demonstration, along with the previous chapters; I hope to justify to myself and to the reader the usefulness of solid waste management web-based application to promote effective solid waste management.

4.1 The Design Phase

To demonstrate the usefulness of a solid waste management web-based application, a prototype product has been developed with Microsoft Visual Studio using C#. The vision for the new web-based solid waste management application is for it to be more generic, and thus usable by other local councils, organizations and groups. If not immediately adoptable by others, it is the hope that the object oriented MVC design of the application will make it easily extensible to accommodate various customization.

During the client meeting phases mainly through the youth group that was launched for this project, requirement gathering documents, use cases, and user stories were drawn up, and feedback was also reviewed. The following is a list defining the various requirements at this stage of the application. The list has been abridged to meet the requirements of the prototype.

Functional Requirements: (What must the application do)

1. Feature a waste management system for district admin, super admin, staff associated with

waste, youth groups and the public in general.

2. Allow a super admin to create/edit/delete countries, regions, district admins and districts
3. Allow a district admin to create/edit/delete constituencies, wards, sections, communities, collection sites, public waste bins, youth groups, youth group admins and staffs specific to its district.
4. Forbid a district admins, youth group admins and staffs to delete their own accounts.
5. Allow youth group admin to edit own profile and register own clients
6. Allow guest user to register as a client of a youth group and view youth groups, collection sites, public waste bins, landfills and submit complaints.
7. Display of static information that is valuable in promoting the slogan TRASH IS MONEY and educating the general public about the importance of clean environment.
8. Allow every user or guest user to view information about collection sites, public waste bins, landfills and illegal dumping sites.
9. Allow the general public to submit complaint related to poor waste management practices or other related complaints.

Non-functional requirements: (Features that are needed but not required to function)

1. Adhere to object oriented principles and use of MVC framework for easy expansion and maintenance.
2. Conform to Latest web standards; HTML5, CSS3, and run on recent versions of Chrome, Firefox, Safari, IE, and Opera.
3. Use PHP and MySQL (required by the client's hosting provider), and not require shell access.
4. Will use English as the source language.
5. Encrypt passwords stored in the database.

Views and Roles in ASP.NET

Views and Roles are very important concepts that were used to develop the system. In this section, the importance of views and roles in the development of the system is explained.

Views - ASP.NET has two approaches referred to as the Database First Approach and the Code First Approach. In the Database First Approach, we define entities, create database and then make the model classes. On the other hand, in Code First Approach, the class diagrams are made first followed by the model classes.

After making model classes, we make controllers which control all the project actions and views.

We can make empty controller or also make default controller which provide MVC entity frame work.

All edit, delete and create actions are controlled via the controller. A controller must always be defined to be in position to access the view.

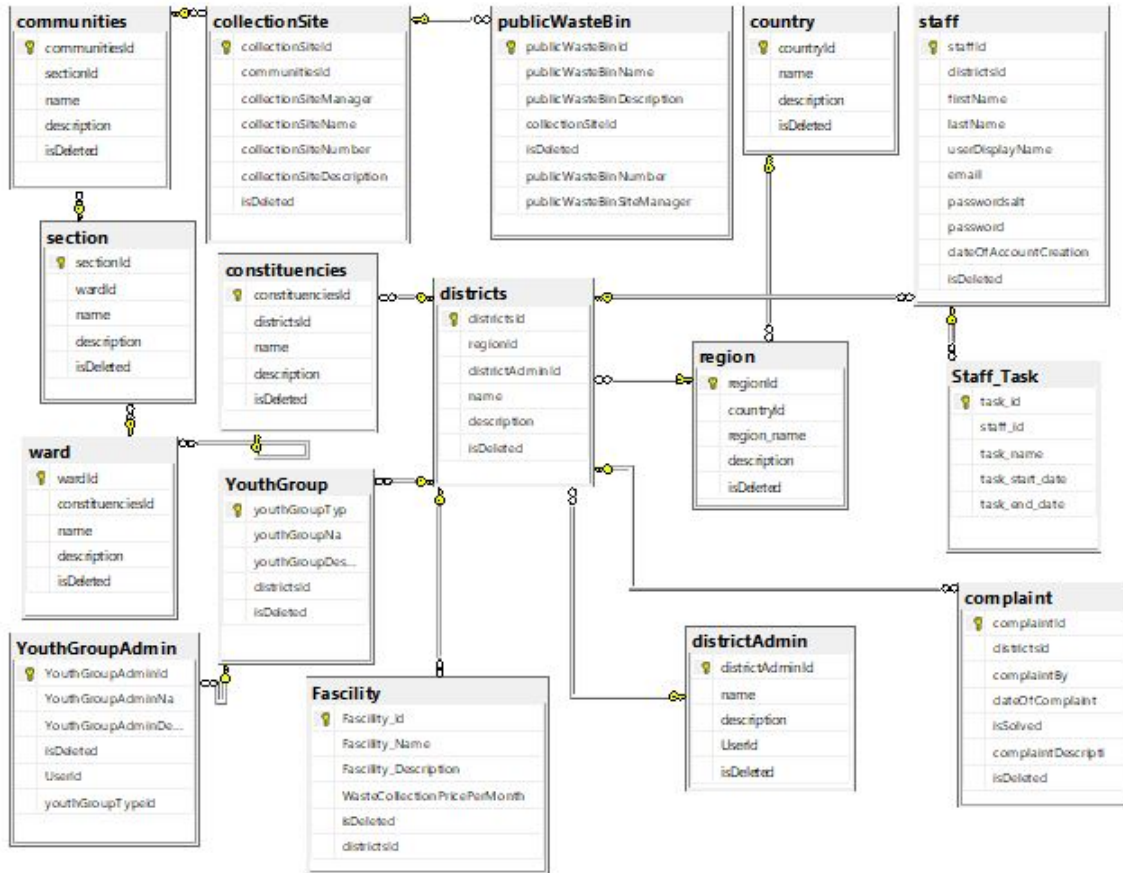
Rights - Rights were defined because the system is used by users with different roles. In ASP.NET, firstly the roles of the system are defined in the Startup.cs file. Secondly, when an action is written in the controller, the written action is authorized according to the roles. For example, since only the admin can create districts, the system admin role is thus authorized to perform the action of creating the districts. By coding only one line above the action in controller performs the magic of authorizing a special user. No one can access the action except that user role. By doing so, admin has the sole right to create and view the district in the admin dashboard and the district admin which is another role will in no way access the districts page via admin dashboard. Through this, we can secure the pages from unauthorized users.

Database design

Having identified all the functional requirements, the business rules were written according to the requirements. The entities are then defined from the business rules and then the relationships between the entities are found. The database created for the system is normalized basically to reduce the repetition data entries and dependency. For instance, when a row is deleted from a table, other tables should not be affected. The same applies for updating any row. It is therefore important for a database to be in the first, second and third normal form.

In the first normal form, the primary keys were defined.

Figure 4.1: Relational Database Design



In the second normal form, partial dependency is reduced. A Partial Functional Dependency is when you have a Composite Primary Key (a primary key that is made up of multiple columns), and one of the non-key columns is functionally dependent on one, but not all of the columns that make up the Composite Primary Key. To resolve partial functional dependencies, you would create a parent table, and place the column(s) that are partially functionally dependent in the parent table. The primary key of the parent table is the column that the column(s) are functionally dependent on.

In the third normal form, we reduce transitive dependency. A Transitive Dependency is when you have a column that is functionally dependent on a column that is not the primary key. For example, when column C is functionally dependent on column B, and column B is functionally dependent on column A, and column A is the primary key. To resolve transitive dependencies, you need to create another table and place the columns that are transitively de-

pendent in the new table. This new table is often a child table. The primary key of the new table is the column that the columns are functionally dependent on in the original table.

Normalization is so important and it was done for this system's database to ensure that information is not affected from any changes in other tables.

Development environment

To develop the web-based application in this thesis, all that is needed is Microsoft Visual Studio IDE with integrated C#, GITHUB and GIT are needed, Microsoft Visual Studio Professional 2015 was downloaded from the web and installed on my local computer. A repository called EWWM which stands for eWomen Waste Management was created on GITHUB. To allow the easy push and pull of changes made to the project, GIT was downloaded from the web and installed on my local machine.

To develop and test on the local development environment, a database is required to be running on the host operating system. In this thesis, MySQL is running on MySQL Server.

Use case diagram

Before any code was written, use case diagrams were created for all the major functions. Although this thesis is worked on by one person to develop a prototype, it is however very important to develop this system as if a team did the development. The software development world is made of teams and hence, if this prototype is to be used for further work on real basis, a team of developers should be in position to work on it. This is why it is important to create that platform of possible team work. One way to do this is by adopting the concept of use cases. One of the most difficult problems in software development is capturing precisely what you want to build. Inaccurate requirement will end-up with significant delay, rework or even unexpected termination of the project. Effectively applying use case technique helps a software development team capturing requirements in user point of view which can be easily understood by both the end-user and your team. Use case driven development support subsequent development activities such as analysis and design and testing. A use case is something that the actors want to do for obtaining observable business goals. They are named with a short verb or verb plus noun phrase. To avoid ambiguity, one should use concrete and specific verbs and nouns.

Theoretically, the end users will perform actions that are supported by the system to achieve their ultimate goals, as identified in use case analysis. Take the prototype in this thesis as an ex-

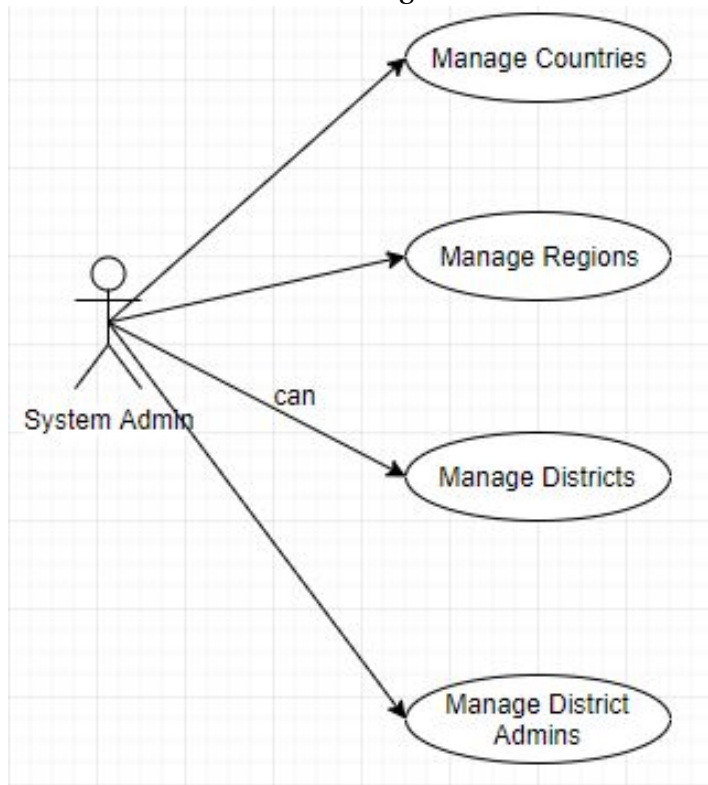
ample. "Manage District Admins" is undoubtedly a business goal, thus a use case. The function to look-up a collection site on a list of sites can also be what a user desires. However, it is not a use case because the action itself does not yield any observable goal.

Four main use cases were selected and their diagrams are displayed here.

Use Case: Manage Countries

The use case depicts the main functions of the System Admin. The system comes along with a super user called the System Admin. Everything starts with this System Admin. You cannot think of managing the waste of a country with this system if there is no country in the first place. The System Admin is directly responsible for the creation of a country of interest. Sierra Leone as a country is divided into regions which are further divided in districts. The System Admin is further responsible to create all these components. Once he has created the districts, he will then create different district admins and assign each to a district for the management of the waste of that district.

Figure 4.2: Use Case: Manage Countries



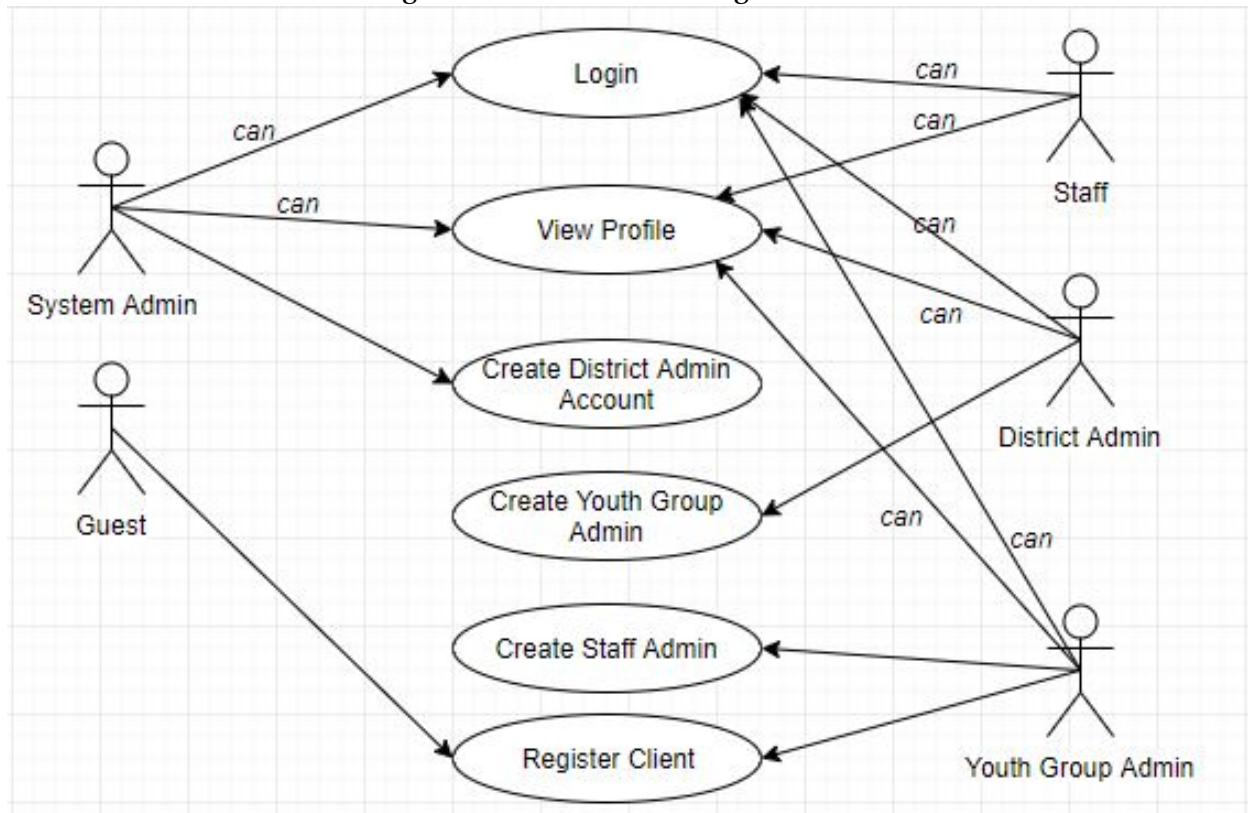
Use Case: Manage Accounts

The system gave privileges to different users such as the System Admin, District Admin, Youth Group Admin and Staff. The System Admin comes along with the system and is responsible for creating the District Admins who in turn are responsible for creating Youth Admins and Staff associated with their districts. The district admins are very core in managing the waste of their districts. As such, most of the interesting functions of the system are carried out by the district admins. Each district admin is associated strictly with one district.

In all, there are four actors who can login into the system to perform functions they have right to. Each of the users is presented with its correct dash board.

It is important to note that the Guest has no associated account. Meaning a guest simply has the right to launch the system and view static information. What is special about the guest is that he can choose to register as a client to one of the youth groups as a client for the waste collection service. Registering in this case simply means expressing interest to be one of the youth group’s clients and nothing else. The youth group will then have the opportunity to view all its clients as a list.

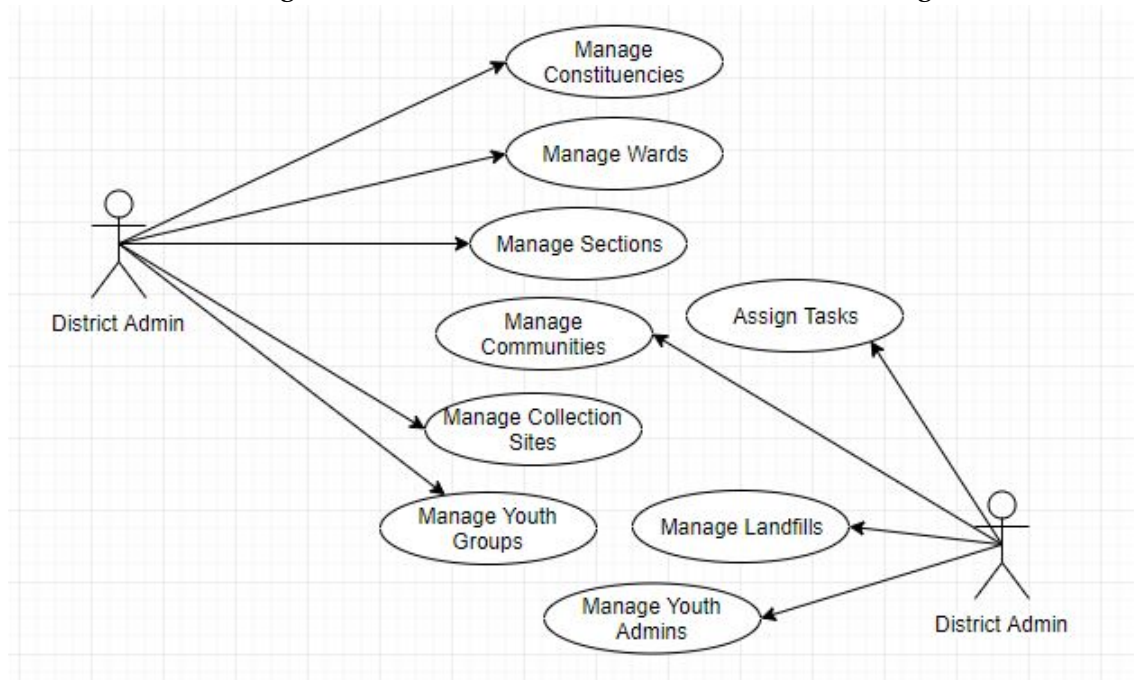
Figure 4.3: Use Case: Manage Accounts



Use Case: Manage District Admin - Waste Management

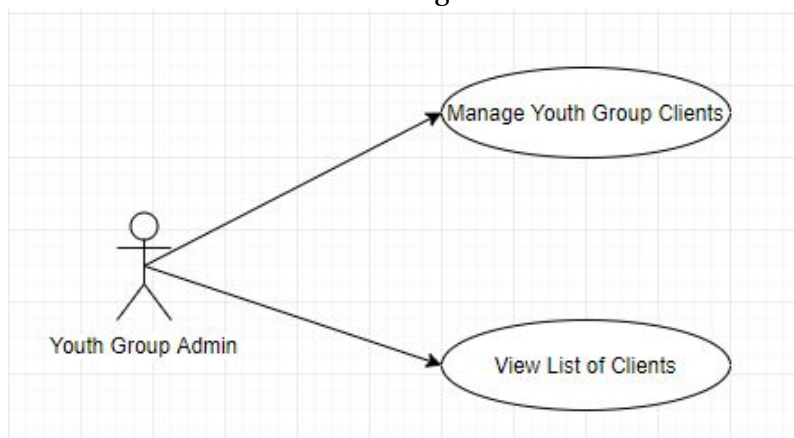
Once created by the System Admin, the District Admin is responsible for management the waste of its district. A district admin is strictly associated with only one district.

Figure 4.4: Use Case: District Admin - Waste Management

**Use Case: Youth Group Admin**

A Youth Group is business start-up in waste management managed by a youth group admin.

Figure 4.5: Use Case: Youth Admin



Chapter 5

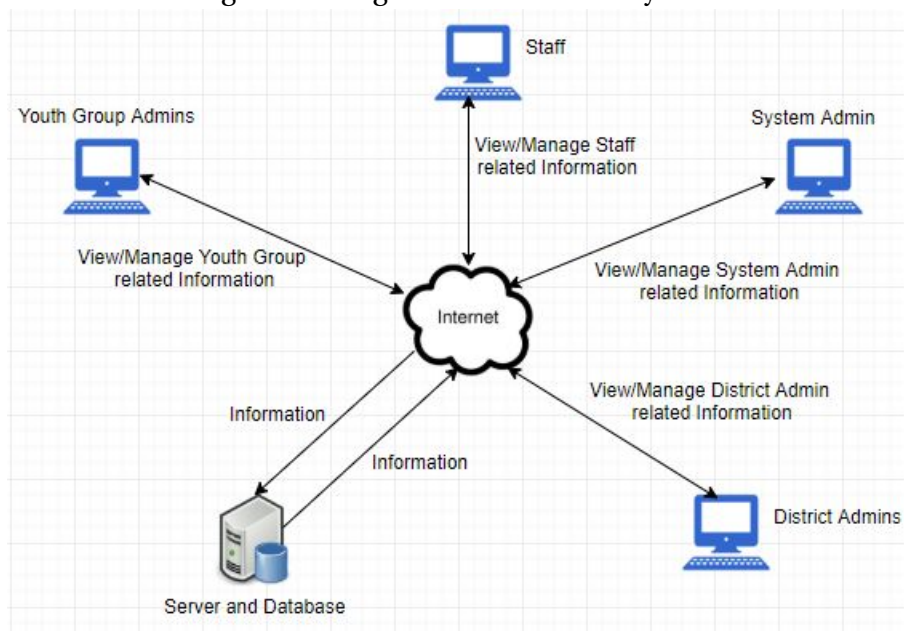
Application Overview

In this chapter, the overview of the developed system and explanations backed by images of the user interfaces of the system will be presented.

5.1 High Level Overview

Figure 5.1 gives a high level overview of this web content management system.

Figure 5.1: High level view of the system.



5.2 Implementation

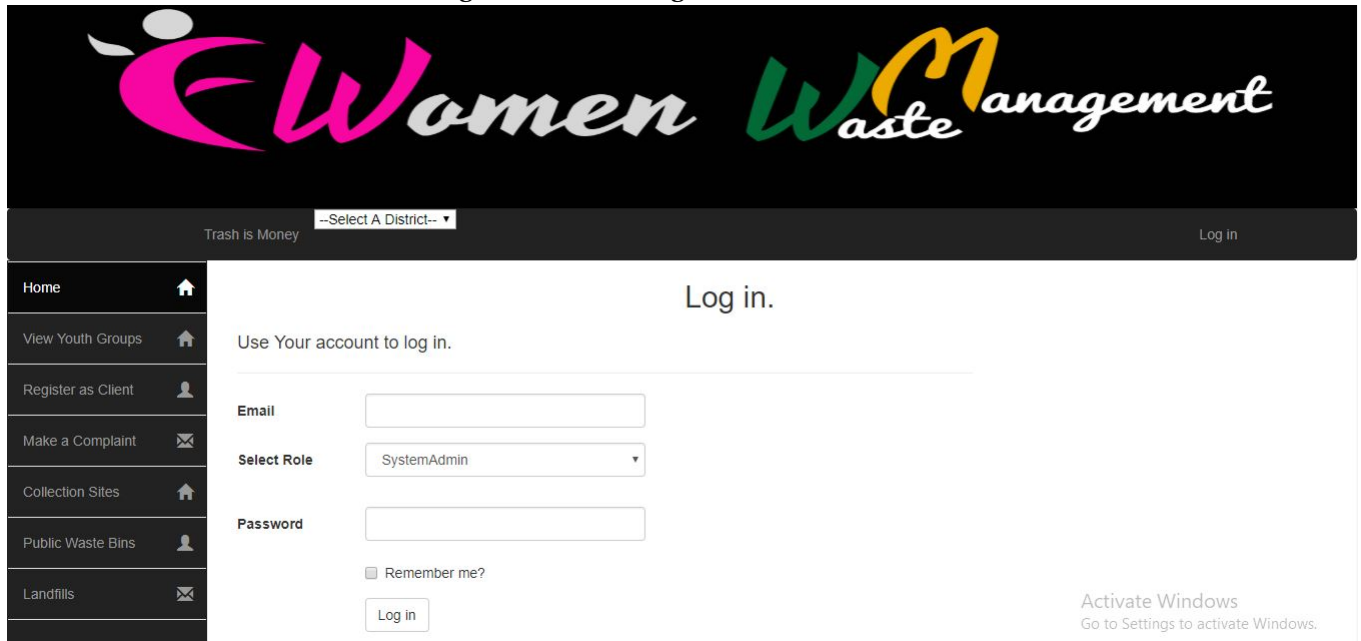
This chapter describes about the implementation of this web content management system. The thesis aims to meet the following requirements and the implementation of these is discussed in this chapter: **Functional Requirements:** (What must the application do)

1. Feature a waste management system for system admin, district admin, staff and a youth group admin.
2. Allow a system admin to create/edit/delete countries and their associated regions, district admins and districts
3. Allow a district admin to create/edit/delete constituencies, wards, sections, communities, collection sites, public waste bins, youth groups, youth group admins and staffs specific to its district.
4. Forbid a district admin to delete their own account
5. Allow youth group admin to edit own profile and register own clients
6. Allow guest user to register as a client of a youth group and view youth groups, collection sites, public waste bins, landfills and submit complaints.

5.2.1 Create Country, Region and Districts by System Admin

The first step in using this system to manage the waste of a country. The System Admin that comes along with the system has the sole right to create a country. Once a country is created, the system admin will then further create the regions and districts associated with that country. These features are password protected, as only the System Admin should be allowed to create an a country and its associated regions and districts. On the front page of the system, there is a link “Login” which on clicking it will allow the System Admin to log in after proper authentication. On successful log in, the System Admin will be directed to a dash board designated only for the System Admin. Displayed below is the Login Interface. You can see that there is a field with a list of the different roles. A user must explicitly select its role to be able to log in. In the case of System Admin, the role is System Admin and the system selects this role by default.

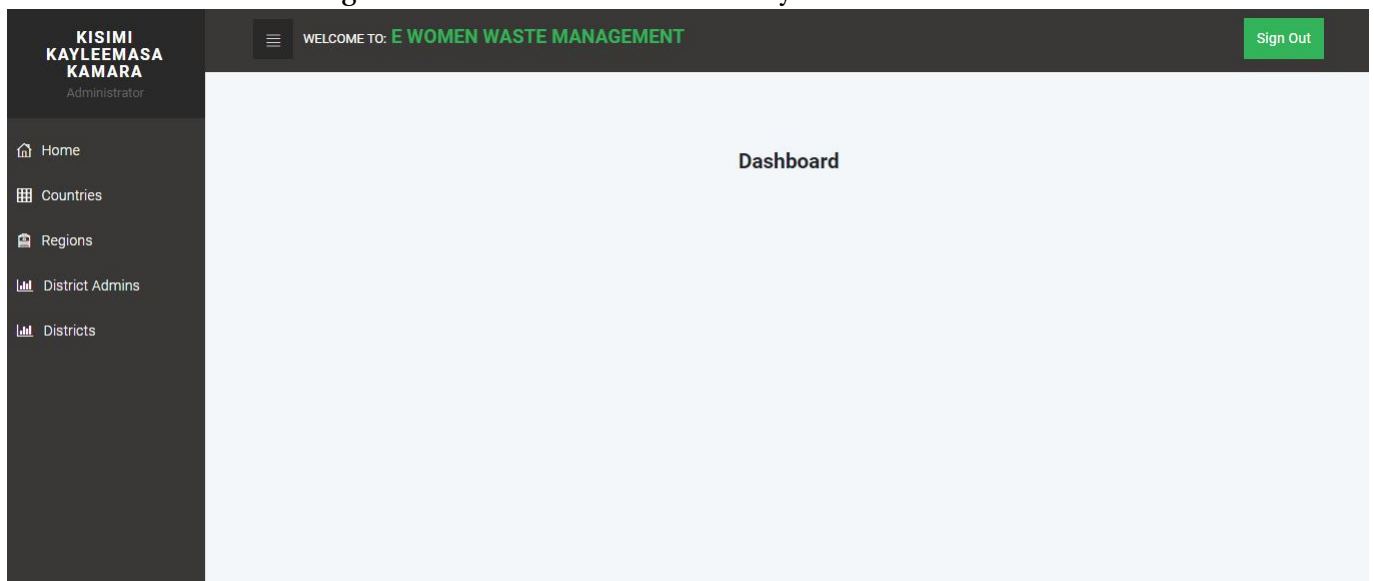
Figure 5.2: The Login Interface



Creation of Country, Region and District by System Admin demonstrated

From the System Admin dash board, one can clearly see four functions that can be only carried-out by the System. These functions are the management of a country whose waste is to be managed and its associated regions and districts. District Admins to manage districts are also created by the System Admin.

Figure 5.3: The Dash Board of the System Admin



Displayed here is the interface for adding a country to the system by the System Admin who has the sole right to do that.

Figure 5.4: The Add Country Functionality

The screenshot shows a web application interface for a System Administrator. The user is logged in as 'KISIMI KAYLEEMASA KAMARA, Administrator'. The main navigation menu includes Home, Countries, Regions, District Admins, and Districts. The 'Add Country' button is highlighted. A modal window titled 'Add Country' is open, containing the following fields:

- Country Name:** A text input field containing 'Sierra Leone'.
- Country Description:** A text area containing the text: 'Sierra Leone is the country for which this system is developed. Sierra Leone is located in the western part of Africa.'

A green 'Add Country' button is located at the bottom right of the modal. The background shows a table with columns for 'Country Name' and 'Actions'.

Using Sierra Leone as a sample country for which this system is developed, a country is expected to be made up of regions. Here is the interface that is used to create the regions of a country.

Figure 5.5: The Add Region functionality

The screenshot shows the same web application interface. The 'Add Region' button is highlighted. A modal window titled 'Add Region' is open, containing the following fields:

- Select Country:** A dropdown menu with 'Sierra Leone' selected.
- Region Name:** A text input field containing 'Northern Region', which is highlighted in yellow.
- Region Description:** A text area containing the text: 'The northern region contains Makeni City which is the biggest city in this this very region. The practical aspect of the project is actually implemented in this city.'

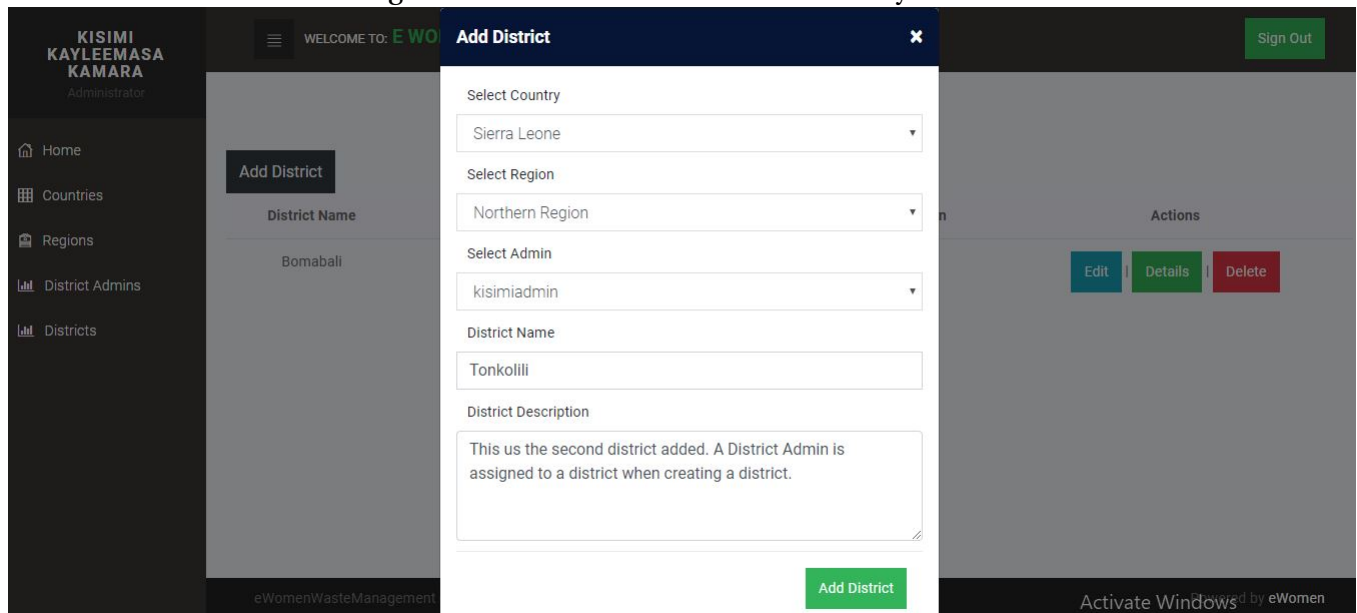
A green 'Add Region' button is located at the bottom right of the modal. The background shows a table with columns for 'Country' and 'Actions'.

5.2.2 Some of the functions of the District Admin

The District Admin is the one who carries out most of the functions that are related in managing the waste of his or her district. Here are some important functions that are performed by the District Admin.

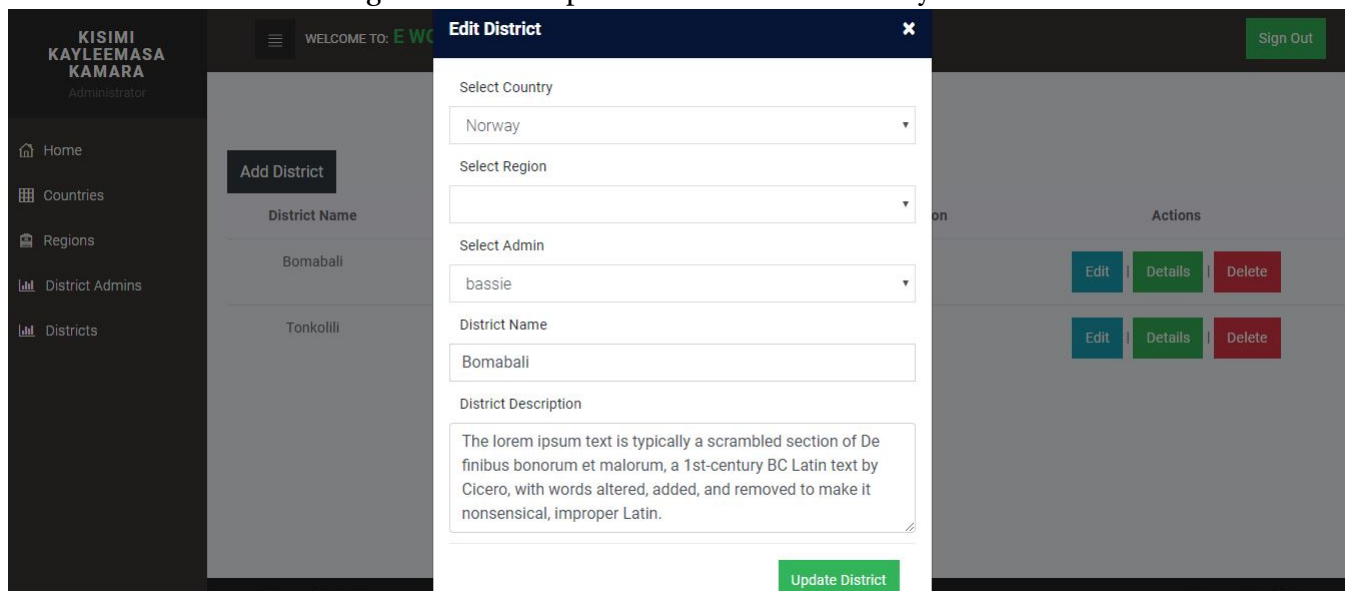
Regions of a country are further divided into districts. After creating one or more regions, the districts of these regions should be created. Here is the interface that is used to create the districts of existing regions. It should be noted that only the System Admin has the sole right to perform this function.

Figure 5.6: The Add District Functionality



All existing districts of regions can be updated, deleted or viewed. For example, the System Admin can use this update function to update an existing district as demonstrated in the screen shot below.

Figure 5.7: The Update District Functionality



One other important function of the System Admin is the creation of the District Admin account. This feature is also password protected, as only the System Admin should be allowed to create such account. To create this account, after logging in, the System Admin needs to enter a valid email address and password. The email address and password will be required by the District Admin for subsequent log in.

Figure 5.8: Create District Admin Account

The screenshot shows a web application interface for creating a District Admin account. The main header includes 'KISIMI KAYLEEMASA KAMARA' and 'WELCOME TO: E WOMEN WASTE MANAGEMENT'. A sidebar on the left lists navigation options: Home, Countries, Regions, District Admins, and Districts. The main content area is titled 'Add District Admin Account' and contains a form with the following fields:

- Admin Name:** A text input field containing 'Yamba Soko'.
- Phone Number:** A text input field containing '1234-123-1200'.
- Address:** A text input field containing '6 Yamba Road'.
- Username:** A text input field containing 'yambasoko'.
- Password:** Two password input fields, both containing '*****'.
- Confirmation:** A text area containing 'Yamba Soko is the District Admin of Bombali District.'

At the bottom right of the form is a green 'Add Account' button. The background shows a table with columns for 'Phone Number' and 'Actions'.

Create Communities

A district that is managed by a District Admin is divided into constituencies and constituencies which are further divided into wards and wards which are further divided into sections and sections which are further divided into communities. Communities are the lowest level and they are very powerful in bringing people together for the common good of their area.

Figure 5.9: Create Communities

The screenshot shows a web application interface for creating a community. The main header includes 'YAMBASOKO District Admin' and 'WELCOME TO: E WOMEN WASTE MANAGEMENT'. A sidebar on the left lists navigation options: Home, Constituencies, Wards, Sections, Communities, Collection Sites, Public Waste Bins, Facilities, Youth Groups, Youth Group Admins, and Staffs. The main content area is titled 'Add Community (Bombali)' and contains a form with the following fields:

- Select Constituency:** A dropdown menu with '37' selected.
- Select Ward:** A dropdown menu with '121' selected.
- Select Section:** A dropdown menu with 'Masuba Section' selected.
- Community Name:** A text input field containing 'Talent Town'.
- Community Description:** A text area containing 'This is the favorite community of the youth group eWomen Waste Management.'

At the bottom right of the form is a green 'Add Community' button. The background shows a table with columns for 'Community Description' and 'Actions'.

Create Sections

Communities found themselves in sections which are headed by a Section Chief. This means, a section can be made up of many communities. Development can be driven in section level but as far as waste management is concerned, we believe it is more effective to focus more on communities to promote our campaign for a clean environment because it is easy for community people to take ownership in cleaning their own communities.

Figure 5.10: Create Sections

The screenshot shows the 'Add Section (Bombali)' form in the YAMBASOKO application. The form is displayed in a modal window over a dashboard. The dashboard has a dark sidebar with navigation items: Home, Constituencies, Wards, Sections, Communities, Collection Sites, Public Waste Bins, Facilities, Youth Groups, Youth Group Admins, and Staffs. The main content area has a 'WELCOME TO: E WOP' header and a 'Sign Out' button. The 'Add Section' form contains the following fields:

- Select Constituency:** A dropdown menu with '37' selected.
- Select Ward:** A dropdown menu with '121' selected.
- Section Name:** A text input field containing 'Masuba Section'.
- Section Description:** A text area containing 'Kisimi lives in this section.'
- Add Section:** A green button at the bottom right of the form.

Create Wards

Sections in turn are found in wards that are headed by elected councillors. The councillors are headed by the district chairman if it is a district or a mayor if it is a city. The councillor is directly responsible to push development in his or her own ward.

Figure 5.11: Create Wards

The screenshot shows the 'Add Ward (Bombali)' form in the YAMBASOKO application. The form is displayed in a modal window over a dashboard. The dashboard has a dark sidebar with navigation items: Home, Constituencies, Wards, Sections, Communities, Collection Sites, Public Waste Bins, Facilities, Youth Groups, Youth Group Admins, and Staffs. The main content area has a 'WELCOME TO: E WOP' header and a 'Sign Out' button. The 'Add Ward' form contains the following fields:

- Select Constituency:** A dropdown menu with '37' selected.
- Ward Name:** A text input field containing '121'.
- Ward Description:** A text area containing 'Ward 121 is found in Constituency 37.'
- Add Ward:** A green button at the bottom right of the form.

Create Constituencies

Wards in turn found themselves in constituencies that are headed by member of parliaments (MPs). MPs are normally considered to be very passive in promoting development in their constituencies. However, by highlighting the good effects of proper waste management in the communities that make up their constituencies, MPs can be motivated to actively be part of the solution to the waste problem. Some MPs are actually very popular and influential but in most cases lack good ideas that can drive development. With this system, MPs will be provided with data that can encourage them to consider waste management as a lucrative activity that can create job opportunities and economic development for their constituencies.

Figure 5.12: Create Constituencies

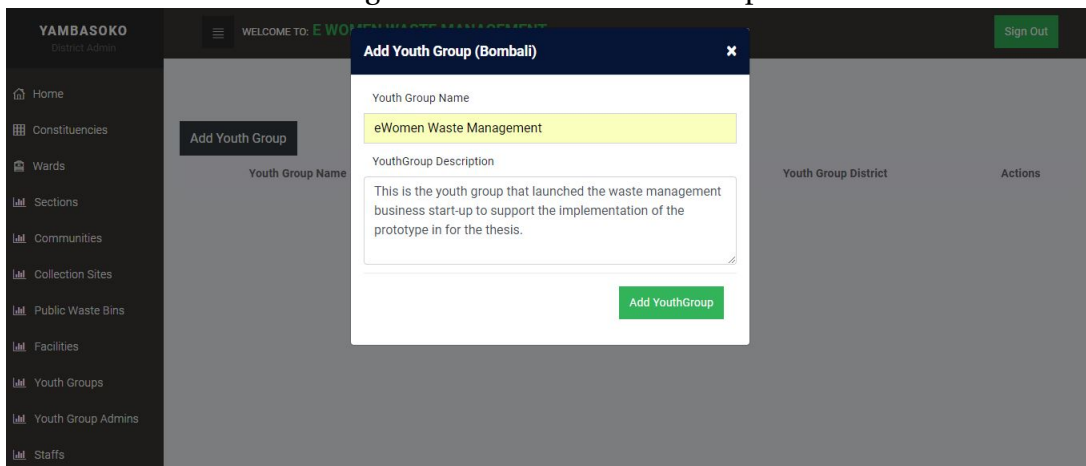
The screenshot displays the 'Add Constituency (Bombali)' form within the YAMBASOKO District Admin interface. The form has a dark blue header with a close button (X). It contains two main input fields: 'Constituency Name' with the value '37' and 'Constituency Description' with the text 'Kisimi Kayleemasa lives in this constituency.'. A green 'Add Constituency' button is located at the bottom right of the form. The background shows a sidebar with navigation options: Home, Constituencies, Wards, Sections, Communities, Collection Sites, Public Waste Bins, Facilities, Youth Groups, Youth Group Admins, and Staffs. A 'Sign Out' button is in the top right corner. The main content area behind the form shows a table with columns for 'Constituency Name', 'Constituency District', and 'Actions'.

Create Youth Group

This project is backed by the launching of a youth group called eWomen Waste Management to promote the slogan TRASH IS MONEY. This group had a great experience with a community in Makeni City called Talent Town. It is the community in which the youth group has the highest number of clients for its door-to-door waste collection service. There is currently a plan to make this community as an experimentation of a model that the group calls the Cleanest Community Model (CCM). The idea is to educate this community about the benefits of a clean environment and then pursue the goal of registering all the households in this community for its waste collection service. The youth group will then guide the community stakeholders on how to lobby for

financial support to help beautify their community with street/road names labels, public trash bins, community library, community park for children and the like. The youth group is also determined to raise fund to support this community. Once this model proves successful in this community, it can be slowly replicated to other communities. The district admin is responsible for managing youth groups in his or her district. To create a youth group, after logging in, the District Admin needs to enter a valid email address and password. The email address and password will be required by the District Admin for subsequent log in.

Figure 5.13: Create Youth Group



The screenshot displays the 'YAMBASOKO District Admin' interface. A modal window titled 'Add Youth Group (Bombali)' is open, showing a form with the following fields:

- Youth Group Name:** eWomen Waste Management
- YouthGroup Description:** This is the youth group that launched the waste management business start-up to support the implementation of the prototype in for the thesis.

At the bottom of the modal is a green 'Add YouthGroup' button. The background interface includes a sidebar with navigation options like Home, Constituencies, Wards, Sections, Communities, Collection Sites, Public Waste Bins, Facilities, Youth Groups, Youth Group Admins, and Staffs. A 'Sign Out' button is visible in the top right corner.

Other important functions of the District Admin are to manage public bins, collection sites and landfills that are in his or her district.

Chapter 6

Summary, Conclusions and Recommendations for Further Work

6.1 Introduction

This research responds to the need for the development of a web-based solid waste management system to aid in the promotion of a sustainable waste management system in Makeni City, Northern Region, Sierra Leone. The purpose of this thesis was to examine the solid waste management status in Sierra Leone using Makeni City municipal, Northern Province, Sierra Leone, in order to develop a web-based solid waste management system for sustainable solid waste management in future. The main objective is the development of a web-based solid waste management system that will be able to capture and display data related to municipal solid waste. Other specific objectives include the following:

- create a database that will enable storage and management of data related to the Municipal's solid waste.
- To identify illegal dump sites in the town.
- To identify and locate where the problems are within the current solid waste management system.
- To establish whether the community is willing to participate and contribute towards solid

waste management.

- To promote the slogan TRASH IS MONEY and encourage youth groups to launch business start-ups in the business of waste management.
- Optimization of waste collection routes. It entails planning cost efficient waste collection route for transportation of waste to the landfills. Existing location of the waste bins and the street maps will provide the proximity of the bins to the waste collection service routes.

Makeni City municipality is situated in the northern region of Sierra Leone. It is a part of Sierra Leone, which has attracted an international organization called Welt Hunger Hilfe to help it address its waste problem. Creole which is broken english is the primary language of communication for the majority of people living in the Makeni City municipality.

Field work for this study started November 2017 and it will continue as long as the youth group used in the study proved viable to sustain its business in waste management. The field work involved establishing business startup in door-to-door waste collection and plastic recycling. In the process, the youth group had the opportunity to talk to different stakeholders, clients, related government institutions and NGOs on how best the waste problem in Sierra Leone can be addressed. This enabled the researcher to get desired data to develop a useful web-based solid waste management system.

The web-based solid waste management prototype was developed and the system developed provided critical insight into the solid waste management business in Makeni City and the country as a whole.

The prototype developed in this study will complement the proposed web-based solid waste management system and recommends the development of a comprehensive web-based solid waste management system in the future.

6.1.1 Current System

Solid waste management system as currently practiced is chaotic and unsustainable in the long run. Waste is not segregated, and the collection and transportation of waste is basic and inadequate. Staffs are not trained. Waste collectors are still stigmatized and the majority has still

not realized that trash is money. Collection and transport methods are rudimentary and pose both human and environmental risk. People, in general, indulge in dumping waste in street corners and gutters. Collection services were found to be infrequent and inadequate. Now that many stakeholders have started to talk about seriously addressing the waste problem, it is important that the administrative aspect is done well. A web-based system can be an effective tool in helping stakeholders to track relevant data and define a new trend in managing waste.

A serious problem in Sierra Leone in all sectors is poor monitoring and maintenance. In most cases, efforts are given to do something but all the efforts are wasted with time because of poor monitoring and maintenance. The same problem is seen in the management of waste. Even as low as 10 public bins are usually poorly maintained. With this web-based solid waste management system, clear roles will be given and data about different facilities will be tracked to enable proper monitoring and ultimate maintenance.

6.2 Conclusions

This research provides a web-based solid waste management system prototype meant to help in the development of a sustainable waste management system in Sierra Leone. Observation of key factors, such as waste generation, waste disposal practices, waste collection and transportation, changing nature of waste to name but few shows that the current solid waste management system is unsustainable in the long run. The proposed prototype will add value to the existing non-functional system. It is lately observed that Sierra Leone as a country is talking in a serious way on how to address its waste problem. International organizations like the World Bank, DFID and WHH are showing interest in supporting Sierra Leone in this. There are plans to present this prototype system to one of these organizations.

The system developed is not complex because the public is able to use it to view the time and day in which refuse will be collected in any location. It also helps youth groups which are business start-ups in waste management to be more efficient in their waste management business activities by using the system to register their clients and getting information on how they can make money from trash. Besides, staff of local councils or NGOs working in the area waste management can use the system to promote waste management in their localities through use

of the system to track important related data.

This research work emphasizes on how best we can address the waste problem through the use of youth groups that should see the waste problem as an opportunity to make a living. The solid waste management system tracks data about waste collection sites, bins and landfills. It provides detail information about refuse for easy reporting and administrative control of solid waste; prevent overflow and eventual blocking of gutters. The use of this waste management system will thus help in mitigating the effect and risks that are mostly experienced as a result of unprofessional handling of waste and the collection sites. Similarly, it aids the prompt delivery of the services of the environmental unit of the local government areas in Sierra Leone.

6.3 Status of the Prototype

Although the development of the system in this thesis was an interactive, customer-driven process that helps ensure the new product addresses customer needs and besides, other good software development practices were used to develop it to meet development specifications, the system in question is still a prototype because it lacks extended testing (>12months).

Though it is a prototype, it has all the features specified in the functional requirements. The system was intensively tested during implementation by the author. Besides, a lady called Beatrice Edwina Koroma, who is currently taking a PhD in Public Health and Nutrition also used her precious time to test the system. The office admin of the youth group eWomen Waste Management was also given the official task of testing the system.

The web application is carefully designed to be user friendly. Its design is very intuitive and informative so that even people with little experience in computers can easily use this system. The system is not packed with unnecessary texts or features. All the buttons and links have short but informative texts to reflect what they suppose to do. This greatly simplifies interaction with the web application as the use of each item on each page becomes known. Making a user manual would have added value to the system but because time constraint, this was left out.

The system is very easy the install. Visual Studio which is the IDE used to develop the system has in it features that enable the easy installation or deployment of the system on any remote server. The system should be seen as a website which can be hosted by any hosting provider

like GoDaddy or HostGator. Sierra Leone has 4G network and this is strong enough to allow the system to run on it efficiently.

6.4 Recommendations for Further Work

One initially desired feature of this system was support for spatial distributions of waste bins, collection sites, landfills and illegal dumping sites. Spatial distributions provide geographical information of all these entities in any ward. Clicking each of the points in a spatial distribution map gives a spatial view of the location or entity clicked on and a brief description of the entity. GIS (Geographical Information Systems) is a useful tool that can be utilized in the search for new dumping sites and managing existing ones. It permits accurate processing of spatial covering a large number of themes, from a variety of sources, enabling tailored solutions for a whole series of applications to be furnished. In addition, web maps can generated and used in an interactive web-based application like this prototype to display maps and execute user-based queries.

The YouthGroup feature can also be extended. For now, the system tracks all youth groups of a district and offers them the possibility to register their clients and view information about new ways of making money from trash. This feature can be further extended to allow these youth groups to capture more information about their clients and generate reports that can help them make decisions that can positively influence their waste management businesses.

Another possible extension will be to create a discussion forum for youth groups, district admins, system admin and the general public about waste related issues. One can even think of making a mobile app on this feature as an extension of this system.

Appendix A

Additional Information

A.1 Extracts of some code

In this section, extracts of the source code of three main features were listed.

A.1.1 THIS IS CONTROLLER CODE FOR THE FRONT PAGE OF THE SYSTEM

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Web;
using System.Web.Mvc;

namespace WasteMangement.Controllers
{
    public class HomeController : Controller
    {
        public ActionResult Index()
        {
            ViewBag.heading = "Web_Based_Solid_Waste
            _____Management_System_for_Sierra_Leone";
```

```
var p = Session["page"];
if (p != null)
{
    if (p.Equals("group"))
    {
        return RedirectToAction("ViewYouthGroups", "Home");
    }
    if (p.Equals("sites"))
    {
        return RedirectToAction("CollectionSites");
    }
    if (p.Equals("bins"))
    {
        return RedirectToAction("PublicWasteBins");
    }
}

return View();
}
public ActionResult Dashboard()
{
    return View();
}
[Authorize(Roles = "DistrictAdmin")]
public ActionResult DistrictAdmindash()
{
    return View();
}
public ActionResult About()
{
```

```
//ViewBag.heading = "About The Waste Management";
ViewBag.Message = "Your_application_description_page.";

    return View ();
}
[HttpPost]
public ActionResult Check(string state)
{
    Session["district"] = state;
    return RedirectToAction("Index");
}
[HttpPost]
public ActionResult page(string state ,string v)
{
    Session["page"] = state;
    Session["district"] = v;
    return RedirectToAction("Index");
}
[AllowAnonymous]
public ActionResult Login(string returnUrl)
{
    Session["district1"] = Session["district"];
    var d = Session["district"];
    ViewBag.ReturnUrl = returnUrl;
    return View ();
}
public ActionResult Contact ()
{
    ViewBag.Message = "Your_contact_page.";
}
```

```
        return View ();
    }

    public ActionResult TrashIsMoney ()
    {
        //ViewBag.heading = "Trash is Money";
        return View ();
    }

    public ActionResult ViewYouthGroups ()
    {

        return View ();
    }

    public ActionResult CollectionSites ()
    {
        ViewBag.heading = "Web_Based_Solid_Waste
        _____Management_System_for_Sierra_Leone";
        return View ();
    }

    public ActionResult CollectionSiteWard (int wardNumber)
    {
        ViewBag.wardNumber = wardNumber;
        return View ();
    }

    public ActionResult AllCollectionSites ()
    {
        return View ();
    }
}
```



```
    public ActionResult PublicWasteBins ()  
    {  
        return View ();  
    }  
}
```

A.1.2 THIS IS THE CONTROLLER CODE FOR THE LOGIN FUNCTIONALITY

```
using System;
using System.Globalization;
using System.Linq;
using System.Security.Claims;
using System.Threading.Tasks;
using System.Web;
using System.Web.Mvc;
using Microsoft.AspNet.Identity;
using Microsoft.AspNet.Identity.Owin;
using Microsoft.Owin.Security;
using WasteMangement.Models;
using System.Data.Entity.Validation;
using System.Collections.Generic;

namespace WasteMangement.Controllers
{
    [Authorize]
    public class AccountController : Controller
    {
        ApplicationDbContext context;
        private ApplicationSignInManager _signInManager;
        private ApplicationUserManager _userManager;
        private wwmDbEntities db = new wwmDbEntities();

        public AccountController()
        {
            context = new ApplicationDbContext();
        }
    }
}
```

```
}

public AccountController (ApplicationUserManager
userManager, ApplicationSignInManager signInManager )
{
    UserManager = userManager;
    SignInManager = signInManager;
}

public ApplicationSignInManager SignInManager
{
    get
    {
        return _signInManager ?? HttpContext.GetOwinContext ().Get<
ApplicationSignInManager > ();
    }
    private set
    {
        _signInManager = value;
    }
}

[AllowAnonymous]
public async Task<JsonResult> UserAlreadyExistsAsync (string email)
{
    var result = (from d in db.AspNetUsers
                  where d.Email == email
                  select d);
    var r = result.Count ();
    return Json (r == 0, JsonRequestBehavior.AllowGet);
}
```

```
    // ...  
    #endregion  
  }  
}
```

A.1.3 THIS IS THE CONTROLLER CODE FOR THE MANAGE COUNTRY FUNCTIONALITY

```
using Newtonsoft.Json;
using System;
using System.Collections.Generic;
using System.Data;
using System.Data.Entity;
using System.Linq;
using System.Net;
using System.Web;
using System.Web.Mvc;
using WasteMangement.Models;

namespace WasteMangement.Controllers
{
    public class countriesController : Controller
    {
        private wwmDbEntities db = new wwmDbEntities();

        // GET: countries
        public ActionResult Index()
        {
            return View((from d in db.countries
                          where d.isDeleted == 0
                          select d).ToList());
        }

        // POST: countries/Create
        // To protect from overposting attacks, please enable the specific properties
```

```
// more details see http://go.microsoft.com/fwlink/?LinkId=317598.
[HttpPost]
[ValidateAntiForgeryToken]
public ActionResult Create([Bind(Include = "countryId ,name, description , isDeleted
{
    if (ModelState.IsValid)
    {
        country.isDeleted = 0;
        db.countries.Add(country);
        db.SaveChanges();
        return RedirectToAction("Index");
    }

    return RedirectToAction("Index");
}

// GET: countries/Edit/5
public ActionResult Edit(int? id)
{
    if (id == null)
    {
        return new HttpStatusCodeResult(HttpStatusCode.BadRequest);
    }
    country country = db.countries.Find(id);
    if (country == null)
    {
        return HttpNotFound();
    }
    string value = JsonConvert.SerializeObject(country, Formatting.Indented, n
{
```

```
        ReferenceLoopHandling = ReferenceLoopHandling.Ignore
    });
    return Json(value, JsonRequestBehavior.AllowGet);
}

// POST: countries/Edit/5
// To protect from overposting attacks, please enable the specific properties
// more details see http://go.microsoft.com/fwlink/?LinkId=317598.
[HttpPost]
[ValidateAntiForgeryToken]
public ActionResult EditCountry([Bind(Include = "countryId,name,description,isDeleted")] Country country)
{
    country.isDeleted = 0;
    if (ModelState.IsValid)
    {
        db.Entry(country).State = EntityState.Modified;
        db.SaveChanges();
        return RedirectToAction("Index");
    }
    return RedirectToAction("Index");
}

// POST: countries/Delete/5
[HttpPost, ActionName("Delete")]
[ValidateAntiForgeryToken]
public ActionResult DeleteConfirmed(int id)
{
    Country country = db.countries.Find(id);
    country.isDeleted = 1;
    db.SaveChanges();
}
```

```
        return RedirectToAction("Index");
    }

    protected override void Dispose(bool disposing)
    {
        if (disposing)
        {
            db.Dispose();
        }
        base.Dispose(disposing);
    }
}
}
```


A.2 Acronyms and Glossary

A.2.1 Acronyms

ASP	Application Service Provider
AYV	African Young Voices
AIX	Advanced Interactive eXecutive
CCM	Cleanest Community Model
EBK	Ernest Bai Koroma
EWWM	eWomen Waste Management
HP-UX	Hewlett Packard Unix
HTML	Hypertext Markup Language
HiB	Hoeyskoele i Bergen
IBM	International Business Machines
IDE	Integrated Development Environment
MP	Member of Parliament
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
MVC	Model, Views, Controllers
MySQL	My - name of co-founder's daughter. SQL - Structured Queried Language.
NGO	Non-governmental Organization
PHP	Hypertext Preprocessor
OS	Operating System
RDBMS	Relational Database Management System
SDG	Sustainable Development Goals
SME	Small-To-Medium Enterprise
SWM	Solid Waste Management
TV	Television
UiB	University i Bergen (University of Bergen)
UN	United Nation
UNCHS	United Nations Commission on Human Settlements

A.2.2 Glossary

ASP.NET - ASP.NET is an open-source server-side web application framework designed for web development to produce dynamic web pages. **GITHUB** - GITHUB is a web-based version-control and collaboration platform for software developers.

C# - C# is a multi-paradigm programming language encompassing strong typing, imperative, declarative, functional, generic, object-oriented (class-based), and component-oriented programming disciplines.

EWWM - eWomen Waste Management is a youth group that was launched to participate in waste management business in Sierra Leone.

GIT - GIT is an open source version control system.

keke - A "keke" tricycle which is now commonly used in some African countries as taxi.

Microsoft Visual Studio - Microsoft Visual Studio is an integrated development environment (IDE) from Microsoft. It is used to develop computer programs, as well as websites, web apps, web services and mobile apps.

Microsoft SQL Server Management Studio (SSMS) - SSMS is an integrated environment to manage a SQL Server infrastructure.

PHP - PHP Stands for "Hypertext Preprocessor." (It is a recursive acronym, if you can understand what that means.

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