ASHESI UNIVERSITY

BINTRIKS: DIGITIZING HOUSEHOLD WASTE COLLECTION

APPLIED PROJECT

B.Sc. Computer Science

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2020

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APPLIED PROJECT

Applied Project submitted to the Department of Computer Science, Ashesi University in partial fulfilment of the requirements for the award of Bachelor of Science degree in Computer Science.

Lilian Mbithe Mwikali

2020

DECLARATION

I hereby declare that this applied project is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:

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Candidate's Name:

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Date:

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I hereby declare that preparation and presentation of this applied project were supervised in accordance with the guidelines on supervision of applied project laid down by Ashesi University.

Supervisor's Signature:

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Supervisor's Name:

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Date:

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Acknowledgements

I would like to express my gratitude to everyone who supported me throughout the course of this project. I would like to thank Ashesi University faculty and my supervisor for their feedback and guidance, my family, friends, and those who helped me with my research by filling questionnaires or taking part in interviews.

ABSTRACT

There exists a communication gap between waste collectors, recycling companies and homes from which the waste is collected. The purpose of this project is to develop a mobile application that serves as a bridge between households, middlemen who collect waste from households, and recycling companies. The application facilitates communication among the three groups for efficient coordination for waste collection process. This will be achieved through predictions and notifications. In this project a mobile application is developed to enable householders to connect with waste collectors in real-time, get contacts of middlemen in their area, provide alternative means of payment such as use of mobile money and credit cards, digitize record keeping and management, as well as showing the next day of collection. Research done showed that the problems homeowners faced was uncertainty on the next day of waste collection, and difficulty in reaching waste collectors. Middlemen complained of having to record transactions on paper and not able to easily connect with recycling companies. Recycling companies needed to be connected with people who could provide constant and reliable source of raw materials. This project solves these problems through the application. After a prototype of the project was developed and given to users for review, the users provided positive feedback on how useful such an application would be in making waste collection efficient.

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Chapter 1: Introduction

1.1 Aim

The purpose of this project is to develop a mobile application that serves as a bridge between households, middlemen who collect waste from households, and recycling companies. The application will facilitate communication among the three groups for efficient coordination and collection of waste. This will be achieved through predictions and notifications. The application will be both mobile and web compatible.

1.2 Background

Adverse climate conditions resulting from environmental pollution is an ongoing discussion in today's world. Environmental pollution from waste produced by households is a common form of pollution. The major pollutants are plastics and metals. Poorly disposed organic waste is also an issue but easily managed as the waste decomposes really fast unlike plastics and metals which may take thousands of years to degrade [1]. The good news is that, with development going on, there are recycling companies which have been set up to recycle mostly plastics and metals [2]. Despite recycling companies being available, plastics are still laying everywhere, especially in big cities with large populations. The question is, why is there pollution and recycling companies barely have enough raw materials? From the research conducted in doing this project through interviews and questionnaires communication between households and the recycling companies appeared to be the main problem. This app aims to address this problem. It will serve as a platform for households where they can indicate when their waste is ready for collection, the recycling companies dealing with that kind of waste will then get in touch with them and collect the waste to avoid overflows, and that way, they too will have consistent sources of raw materials.

Currently, households and companies or individuals who collect waste from them use physical book-keeping records of payments made, user details, dates of transaction and how frequently waste is collected. The problem with this type of record keeping is that, it is cumbersome to carry the physical records around from one house to another during waste collection. In addition, the records can easily be accessed by unauthorized parties hence compromising the privacy of users' personal details. The records can also be easily tampered with compromising security and causing chaos due to inaccurate data. Also, referring to older records is time consuming, and the physical records can easily get lost and no backup is available. Bintriks application will establish a more reliable and secure way of keeping records in a database. This way, data will be readily available as long as one has access to the application, there will be data backup in case of losses and data security and privacy will be guaranteed.

Cash payment is used as the main means of payment by people who engage in waste collection from households. Only a few of them use mobile money as a means of payment. Use of cash payment comes with a lot of challenges such as: limitation where the amount of money is huge, lack of security as it is relatively highly prone to theft and loss, as well as both parties have to meet physically for payment, and this could be time consuming. The application will solve these problems by integrating online payment systems on the application such as PayPal, payment by credit card, and mobile money payment.

From the research, it was evident that the waste collectors do not have an exact date on which they carry out their services. Due to this, homeowners stated to face challenges of bins overflowing due to delayed pick-ups. Through this application, whenever a bin is full the user will log it on the app and waste collectors who work within that location will be notified, then they can accept the request and collect the waste so as possible. The people who collect the waste will also

be able to set their next date of collection on the application, and the user will be able to see the next dates of pick up on their side. This will ensure efficiency and good environmental health by ensuring bins don't overflow, while also saving the homeowner the problem of uncertainty.

1.3 Related work

As of the year 2015, Ghana was producing a total of waste of about 12710 tons with every person estimated to generate about 0.47 kg per day. Of all the waste, organic waste was the most by 61%, plastic followed by 14%. Metals were recorded to be only 3% [3]. This shows that plastics and metals form more than a quarter of all waste produced. If all that waste was irresponsibly disposed due to poor connections with recycling companies, then it would leave the environment in bad condition by increasing levels of pollution in Ghana considering that plastics and metals are non-biodegradable and really harmful to the environment.

By the year 2010, the production of plastics had been estimated to rise to 300 million tons [4]. This limit is likely to have already been by passed by now considering the increased number of production of plastics over the years. Despites plastics having some societal benefits such as packaging and also being used in the medical field, their poor disposal poses threats to the environment and organisms residing in it by making living conditions of natural habitats inhabitable and undesirable. Plastics can also cause diseases to humans and wildlife through their leaching chemicals [4]. Use of plastics has also been said not be sustainable as a lot of energy goes into manufacturing them while they have a lot of undesirable effects to the environment [5].

Since poor disposal of plastics will lead to environmental pollution, there are various ways which have been put in place to control pollution by plastics. Some countries like Rwanda and Kenya have decided to totally do away with production and use of plastics [6, 7]. Ghana still uses

plastics. Since this project focuses on Ghana, a solution to pollution from plastics will be controlling how they are disposed. Burying of plastics in landfill is a common method used. Recycling is also used even though it is not as effective due to the communication gap between households and recycling companies, hence some people just end up disposing the waste anywhere causing littering which in turn leads to pollution. Recycling is considered to be more effective as compared to burying of waste(plastics/metals) [8].

1.4 Objectives

1. Facilitate efficient communication between households, middlemen, and recycling companies who deal with waste collection.

2. Reduce rates at which households poorly dispose waste instead of taking it to recycling companies.

3. Boost the economy through increased output from recycling companies as they will have enough raw materials from consisted sources.

4. Contribute to creativity and innovation by giving tips on tips of reusing non-recyclable waste materials.

5. Improving the living standards of households and individuals who get money incentives for submitting their waste to recycling companies.

6. Facilitate effective waste collection by showing the next date of waste collection.

7. Create an online database for record keeping avoiding loss of information and to ensure easier accessibility and data backup.

1.5 Plan for Requirement Analysis

For the requirements of this project to be helpful, reliable and useful in solving user needs, research was conducted through surveys such as use of questionnaires, conducting interviews, and observations.

The following were the steps to taken in obtaining the user requirements:

1. Coming up with interview/questionnaire questions.
2. Submitting the questions to the Ashesi Institutional Review Board for review and verification.
3. I went to the field (various households, recycling companies, and people who collect waste from household) to conduct interviews and do observations after the board approved the questions.
4. Analyzing of the responses to interview questions, questionnaire questions, and observations made.
5. Use of the results to come up with both functional and nonfunctional requirements of the application.

Chapter 2: Requirement Analysis

2.1 Approach for requirement gathering

To build an effective system, there is a need to understand what the people who will be using the application really need. A couple of surveys were conducted so as to understand what the stakeholders really needed and expected from the application. The stakeholders involved are households who generate the waste to be collected, the middlemen (bola men) who act as links between the households and recycling companies, as well as the recycling companies. To gather information from the stakeholders the following means were used: conducting face to face interviews, sending out questionnaires to stakeholders for them to fill.

2.2 Case Scenarios

Case scenario 1: Nana Efua is resident at one of the Estates in Madina. Today marks exactly 2 weeks since waste was last picked from her home. Due to this reason, the bin is overflowing, it is smelly and starting to attract insects. Nana does not have a specific person to collect the waste and she requested the one who last collected her waste to come for collection after a week and that did not happen. Nana decides to rant on her WhatsApp status and see whether any of her friends will help with the situation. One of her friends says that she has an agreement with one of the bola men to collect her waste weekly and get paid at the end of the month, but the person does not always show up every week and she does not like giving the job to another person in the middle of the month as she will have to pay double. Another friend complains about how one time they did not have cash to pay but had money in her credit card, and had to go borrow money from a neighbor to pay for the waste collection as it was the only acceptable means of payment. Another one talks about the trouble he had recalling his previous transactions after losing the "card" which is filled

during each collection. Some friends give Nana Efua contacts belonging to middlemen. She tries to reach a few with no success as some say they cannot come to collect waste for only one person while others say they only work in particular days of the week. Finally, one agrees to come collect the waste from Nana's house after a conversation during which Nana assures to pay 10% more than what she would normally pay for the service.

Case scenario 2: Kofi is a middleman who collects waste from houses and takes it to a recycling company in Accra which specializes in recycling plastics. It takes Kofi a long time to sort the waste into different types of waste to be able to only take plastics to the recycling company. On some days, Kofi decides to just dump the waste into a landfill which is like a center for dumping waste in Accra as it saves him time which would otherwise go into sorting the waste. Kofi wishes his clients sorted the waste and then he won't have to contribute in polluting the environment by dumping plastics which could have been recycled at the landfill. Another challenge Kofi faces is that he does not have consistent clients, at times, when he goes to the houses he collects waste from, he finds that the waste has already been collected and he ends up wasting a lot of time and energy moving to houses where he is not certain whether there is waste to collect or not.

Case scenario 3: Ecoplasti is a recycling company in Accra which recycles plastics to make home appliances and utensils. One of the largest challenges faced by Ecoplasti is inadequate raw materials(plastics). Ecoplasti has partnered with individuals who collet plastics from households as well as other companies which do the same for supply of plastics. Sometimes, the middlemen bring unsorted waste to Ecoplasti and they have to spend more money and labor in ensuring that the waste is sorted.

2.3 Use Case diagrams

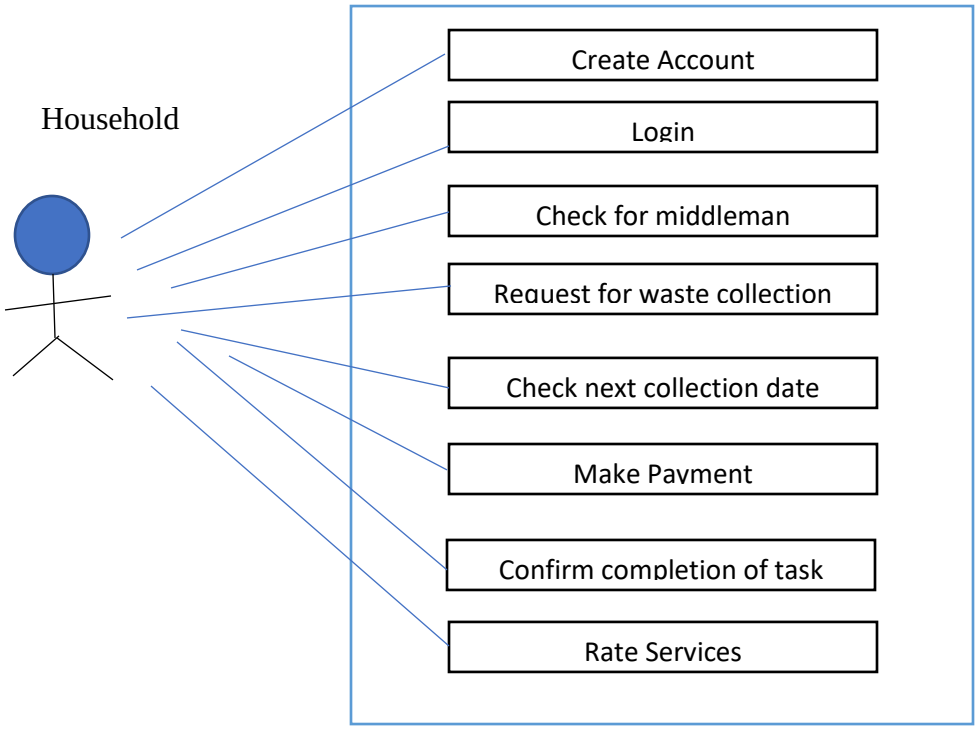

Figure 2.1: Use case for householder

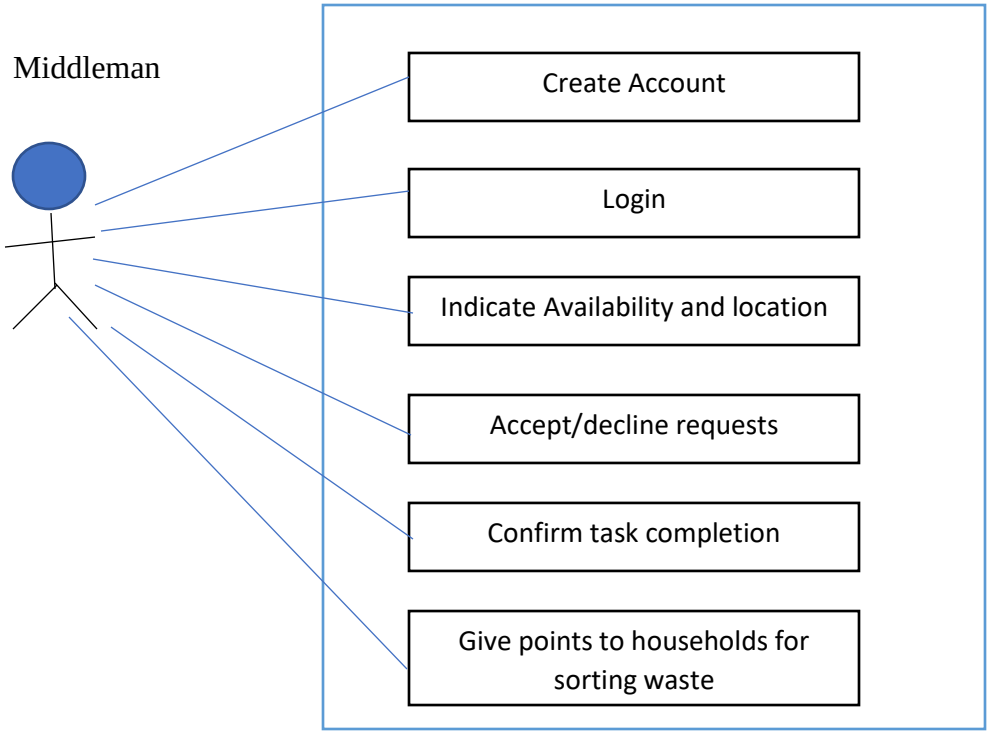

Figure 2.2: Use case 2 for middleman

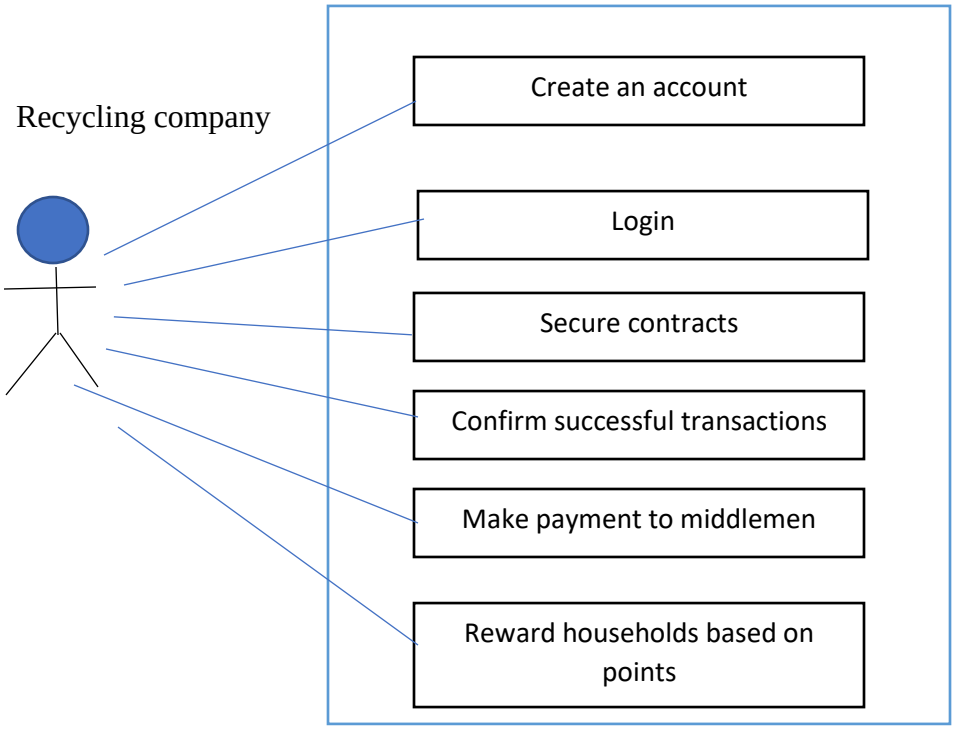

Figure 2.3: Use case for recycling company

2.4 Functional requirements

The application should be able to:

i) Allow household members, middlemen and recycling companies to create accounts.

ii) Allow people who have accounts to successfully sign in with correct credentials.

iii) Make it possible for households to see middlemen working in their area on a given time (real time).

iv) Allow households to send requests for garbage collection.

v) Allow middlemen in a given area to see requests send from households nearby.

vi) Make it possible for households to get notifications when their request is accepted by a nearby middleman (bola man).

vii) Show distance between the household and the available middlemen as well as the one they requested to come for the waste as they approach.

viii) Allow middlemen to accept requests for waste collection from households

ix) Enable middlemen to book contracts with recycling companies.

x) Keep data on transactions from different users in database.

xi) Predict the next date for waste collection based on the kept transaction data on when waste was collected and type of waste. This will be an alternative for people who might not want to connect with middlemen available but want to be consistent with a particular company/middleman.

xii) Send notifications to middlemen and households about the predicted date for waste collection.

xiii) Enable users to pay using mobile money or credit cards.

2.5 Non-functional requirements

i. The application should be easy to use for the users.

ii. The application should ensure that private data belonging to users is secured from access by unauthorized parties.

iii. The date predictions for collection time and notifications should be as accurate as possible so as not to mislead users.

iv. Have a backup for data for retrieval in case of any losses.

Chapter 3: Architecture and Design

3.1 Project Overview

This project involves developing an application that serves as a platform linking households to middlemen (who collect waste from the households), and recycling companies which work with the middlemen. The project also aims at solving the problem of inconsistency in waste collection by using already collected data to predict the next most convenient date of waste collection, and also by showing in real time available middlemen in a certain area at a given time and the user can send a request for waste to them and they can accept or decline it. The system will also digitize the whole process of waste collected including a more convenient information storage system which uses a database instead of physical records which are prone to damage. It will also provide diverse means of payment such as use of credit cards and mobile money to give users more options other than payment by cash.

3.2 Modules

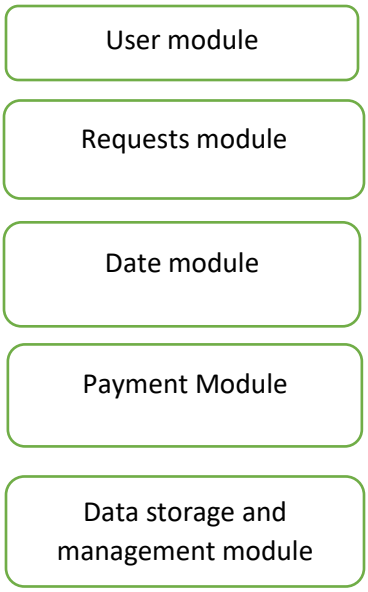

Figure 3.1: Application modules

The main modules in the system are user module, requests module, payment module, prediction module and data storage and management module. The user module is made up of households, and recycling companies. The requests module enables users to request for services and get notifications. The payment module authenticates, and processes payments made through the system. The date module shows the user the next date of collection for various bola men in their location. The data storage module will ensure efficient, secure, and reliable data storage of user details and transactions details.

3.3 Architecture

The modules are implemented as outlined using the following architectures: Layered architecture, client-server architecture and, pipe and filter architecture.

3.3.1 Layered Architecture

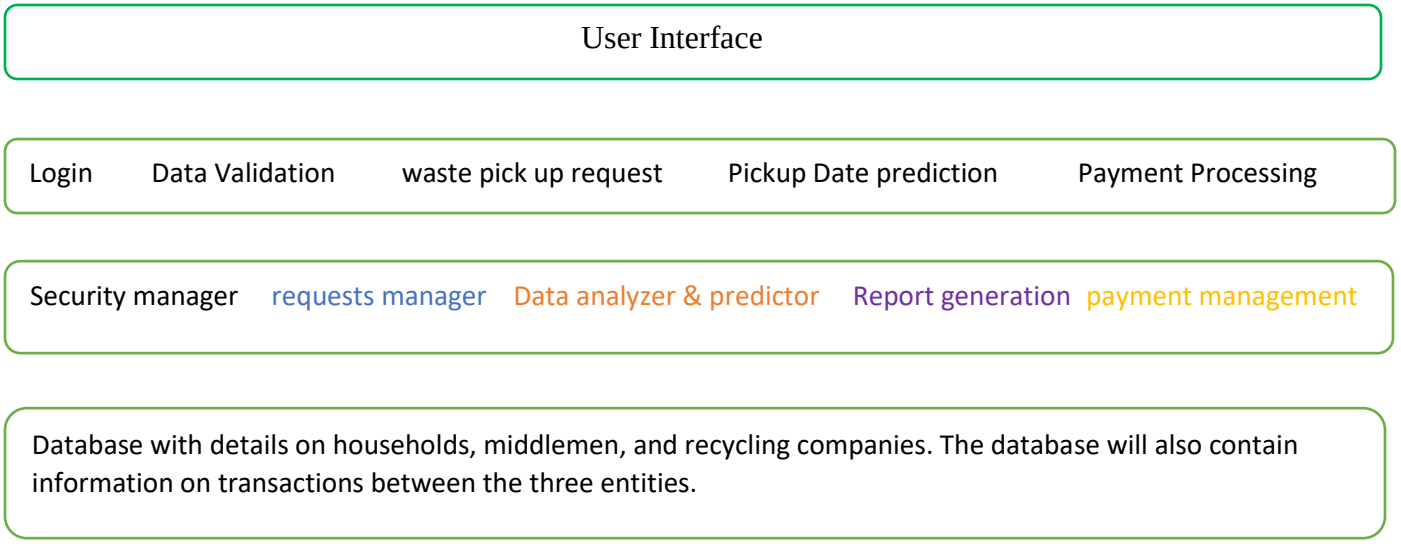

Figure 3.2: Layered Architecture

3.3.1.1 Reasons for using Layered Architecture

-This architecture will enable new features to be built on older ones. This will be useful in the case where new user requirements call for additional features to the system. With constant user feedback, this is always a possibility.

- It is easy to manage as a layer can be replaced/ made changes to independently.

- This system requires high security level as it contains user's personal data as well as transactions and payments, and layered architecture ensures this because it supports multi-level security.

3.3.2 Client-server architecture

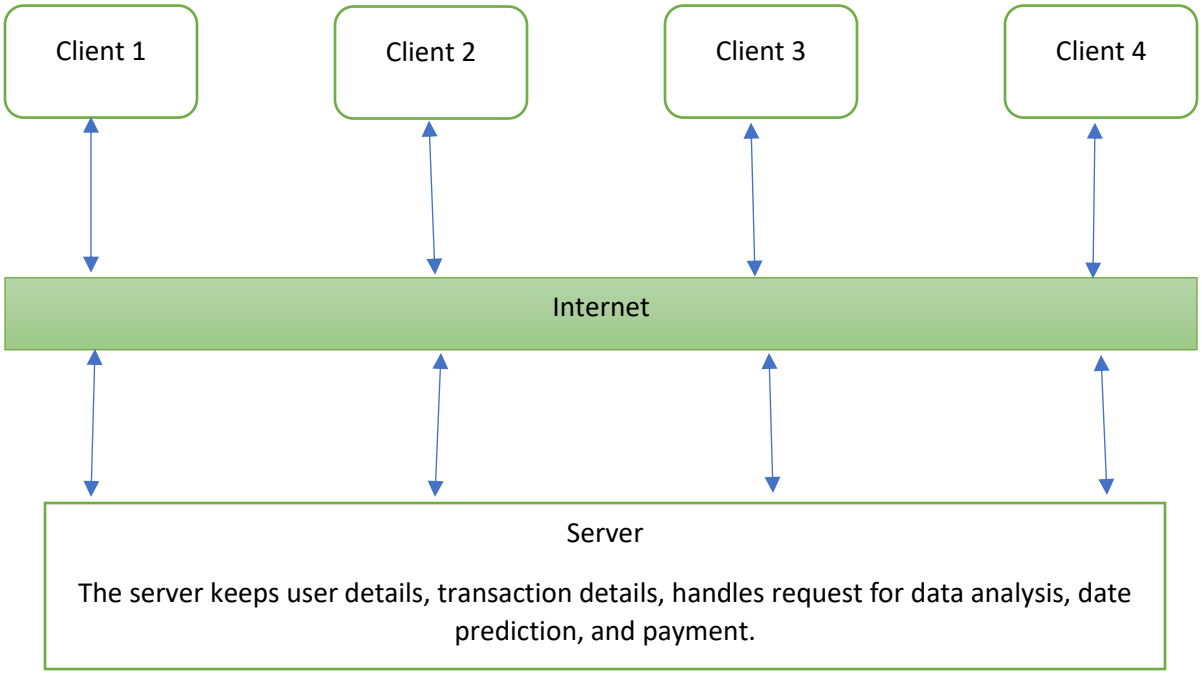

Figure 3.3: Client-server architecture

3.3.2.1 Reasons for using client-server Architecture

- The system will have a shared database which will be accessed by clients from different locations, hence making replication of the servers possible in different areas.

- The servers will be available through one network, hence making implementation faster because it will only be carried out by one service.

3.3.3 Pipe and Filter

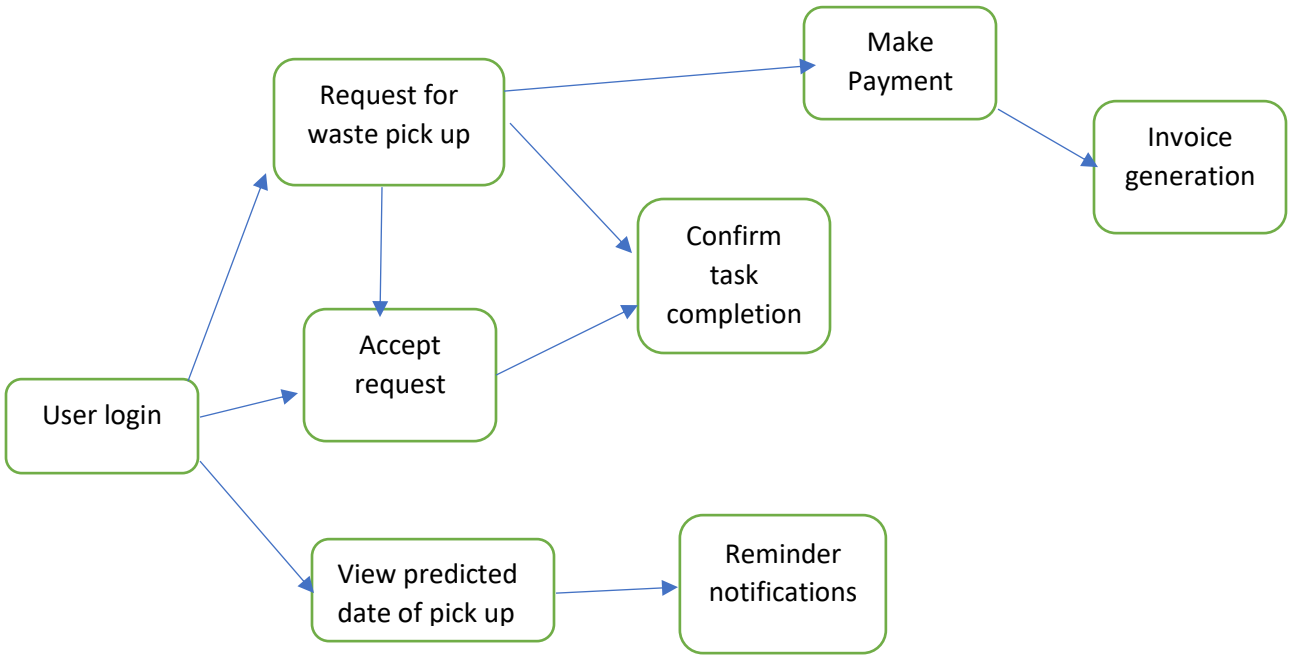

Figure 3.4: Pipe and Filter Architecture

3.3.4 Reasons for using Pipe and Filter Architecture

- This architecture is suitable because the system is a data processing application. Inputs will go through different stages in the system so as to produce outputs. For instance, inputs on user details, and transactions the user has had before will be used in date prediction.
- It is easy to make changes to the architecture. This is necessary in the case of this system because the user requirements are likely to change based on feedback from users when they interact with the system's prototypes, or the system itself at the testing stage of development.

- This architecture is flexible as it gives options of either implementing the system sequentially, or concurrently.

Chapter 4: Implementation

4.1 Overview

This chapter generally talks about the building of the application and tools and resources used. It provides details on tools, libraries, frameworks and programming languages used. It also contains snippets different parts of the application as well as code.

4.2 Implementation tools and technologies

4.2.1 Frameworks

4.2.1.1 PhoneGap is an open source framework used in developing cross-platform mobile applications. I chose to use PhoneGap because it is convenient for creating cross platform applications, which will enable users using different operation systems to be able to use the Bintriks application. PhoneGap also has a lot of plugins such as geolocation that were useful in developing this application.

4.2.1.1.1 Plugin APIs Used

- **Geolocation**. This is used to get the location of homeowners and that of waste collectors, and then show it on a map on which they are able to connect with each other in real time.
- **Network Information**. This plugin is useful in determining whether householders are online or offline. When the they are online, they have a choice to connect with waste collectors in real time, and when they are offline, they are able to see a list of middlemen who work within their area and get their contacts to call or message them.

4.2.1.2Bootstrap 4 is an open source development toolkit used for styling interfaces. It is used alongside Hyper Text Markup Language (HTML), JavaScript and CSS. In this project, Bootstrap 4 was used in styling the user interface of the mobile application.

4.2.2 Programming languages

4.2.2.1 HTML

Hyper Text Markup Language (HTML) is a programming language used in describing the layout of webpages. It consists of different elements such as body, headings, form and paragraphs. These different elements are coded to include content to be rendered on the webpage.

4.2.2.2 JavaScript

JavaScript is a scripting language used in webpages. It is a light weigh programming language and it is interpreted on in-time basis. In this project JavaScript is used alongside jQuery and Ajax to serve as a link between the front-end and the back-end.

4.2.2.3 CSS

Cascading Style Sheet (CSS) is used in with HTML to format the layout of webpages. CSS styles web pages to appear presentable by controlling properties of html elements such as proportions, color, text style, as well as how images will appear on the webpages.

4.2.2.4 PHP

Hypertext Preprocessor (PHP) is a scripting language used for back-end development. In this project, PHP was used with SQL to communicate with the database.

4.2.2.5 SQL

Structured Query Language (SQL) is a language that is used to communicate with the database by executing different commands to perform actions such creating databases and tables, adding data to the databases as well as editing data which already exists in the database.

4.2.2.6 Python

Python is a high-level language interpreted programming language.

4.2.3 Libraries

jQuery is a JavaScript library which is way more simplifies than 'vanilla' JavaScript making it very convenient to use.

jQuery mobile is a user interface system that is used to create responsive applications and websites. It is HTML-5 based.

Ajax is a library that makes it possible for applications and webpages to respond asynchronously. It achieves this by constantly exchanging data with the server.

4.2.4 APIs

Mapbox Maps API. This API is used together with coordinates from the geolocation plugin to locate waste collectors on a map in real time.

Flutterwave API: This API is used to process payments. Options offered are mobile money and credit cards.

4.2.5 Other tools

Visual Studio Code and **Sublime** were used as the primary source code editors

Localhost was used as the server that hosted the project locally during development before it was hosted online.

Chrome, Firefox, and **Edge** were the browsers used to view the application as well as test it for browser compatibility.

Adobe PhoneGap Build was used to generate cross platform mobile applications for the various platforms (Windows phone 8, Android, and iOS).

4.3 Implementation process

Front-end

HTML was used to render content to webpages, CSS and Bootstrap4 were used for design and jQuery-Ajax was used to link the backend and the front-end so that the front end does not have to directly communicate with the backend

Back-end

PHP was the main programming backend used to program the backend together with SQL. XAMPP was used as the server during development.

4.4 Design and functionality descriptions

The Bintriks application is divided into 5 main modules: the user module, the real-time module, date module, payment module, and data storage and management module.

4.4.1 Implementation of the user module

In this module comprises in registration. It is made up of the Sign-Up feature, Login, and Forgot password. HTML forms are used to collect data from the user and submit it to the database,

collect data to be used for comparison to verify login, and to collect email address to be verified with emails in database and be used to reset password.

4.4.2 Implementation of the real-time connection module

This module is the development of the feature that enables householders connect with middlemen in their area in real-time. The Geolocation Cordova PhoneGap plugin is used to get the coordinates on both the householder and the waste collectors. The coordinates are then put on a map generated using the Mapbox map API. Once the user is able to see all the waste collectors in their location, they then click on the objects representing the middlemen on the map and send requests for waste collection. There is also an option for the user to cancel the request in the first 5 minutes after request is accepted by the middleman, else, a cost is incurred for inconveniencing the middleman.

4.4.3 Implementation of the payment module

This module is about implementation of digital methods of payment. In this case, the householder has an option of using mobile money to pay the waste collector.

4.4.4 Implementation of the data storage and management module

module is about the database. User information and user transactions are all kept in the database. When a user submits the Sig Up form when creating an account, the information is kept in the database and used for other functions such as user verification. Also, when user edits their password, the information is edited accordingly in the database. When a user confirms completion of a transaction, the details of that transaction are automatically logged into the database.

Chapter 5: Testing and Results

5.1 Overview

This chapter discusses the different types of testing used in checking whether the functionalities of the application were met and working as expected. The testing is to validate the usability and effectiveness of the application. The types of testing used for this project are browser compatibility testing, system testing, install testing and back-end testing.

5.2 Browser compatibility testing

The browsers on which this test was carried are chrome, Firefox and Edge. The test on browsers was done because the application is supposed to be both mobile and browser compatible. The application worked fine across all the browsers.

5.3 System testing

5.3.1 Registration

5.3.1.1 Sign Up

This test was carried out to test whether a new user account was created by inserting data filled on the signup form into the database. The sign Up is supposed to have only one instance of a user of a given type. For example, if a householder with the email john@gmail.com already exists in the database, another householder cannot sign up with the same email, but it is possible for a middleman or a recycling company to sign up with the same email. Below is a table with the different instances used to test that the sign up worked as needed.

5.3.1.1.1 Sign Up Test

Figure 5.1: Sign Up Test Table

Test	Response	Outcome
Submitting an empty form	The form does not submit but instead requires all fields to be filled. Expected outcome.	Fail
Householder, Middleman or recycling company signs up with an email they have created an account with before	User account already exists. Expected outcome	Fail
Middleman/waste collector signs up with an email used by a householder or a recycling company	Data inserted to database. Expected outcome.	Success
User signs up with a new email address	Data inserted into the database. Expected outcome.	Success

5.3.1.2 Log In

This test was carried to make sure that login worked only on the instances where the correct login credentials were provided. The details required to be filled for login to work are username and password. Below is a table summarizing the tests:

5.3.1.2.1 Log In Test

Figure 5.2: Log In Test Table

Test	Response	Outcome

Submitting an empty form	All fields are required to be filled before submitting. Expected outcome.	Fail
Correct username and wrong password	Wrong login credentials. Expected outcome	Fail
Wrong username and correct password	Wrong login credentials. Expected outcome	Fail
Correct combination of username and password	Log In successful. Expected outcome	Success

5.3.1.3 Forgot Password

This test was conducted to make sure that only the rightful user is able to change the password to a given account. Once the user clicks on “forgot password”, they are required to provide their email address for a reset link to be sent to it. Below is a table summarizing the tests done on this feature:

5.3.1.3.1 Forgot Password Test

Figure 5.3: Forgot Password Test Table

Test	**Response**	**Outcome**
Submitting an empty email form	Fill email address to submit form. Expected outcome.	Fail
Filling an email address not in database	The email address provided does not exist in the system. Expected outcome	Fail
Filling email address existing in database	A link has been sent to the given email address, click on the link to reset password	Success

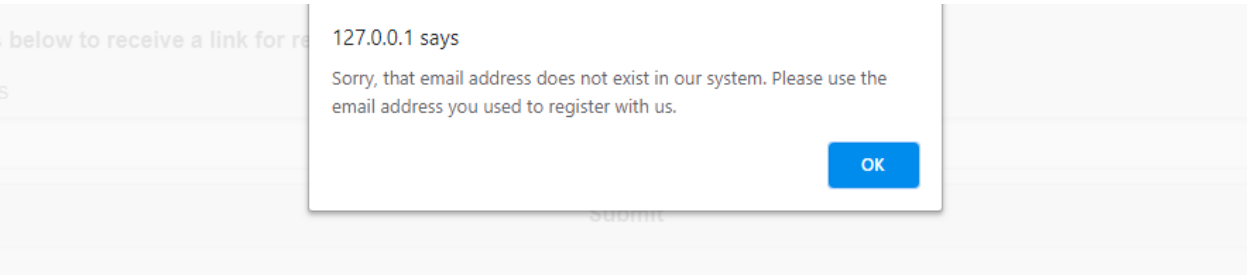

Figure 5.4: Email not in database notification

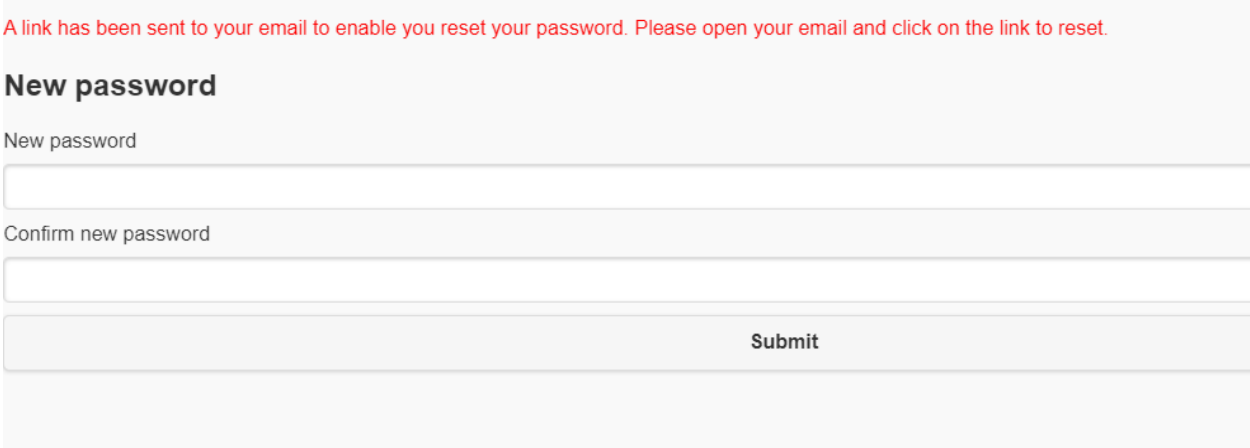

Figure 5.5: Email in database notification

Figure 5.6: Homeowner Homepage

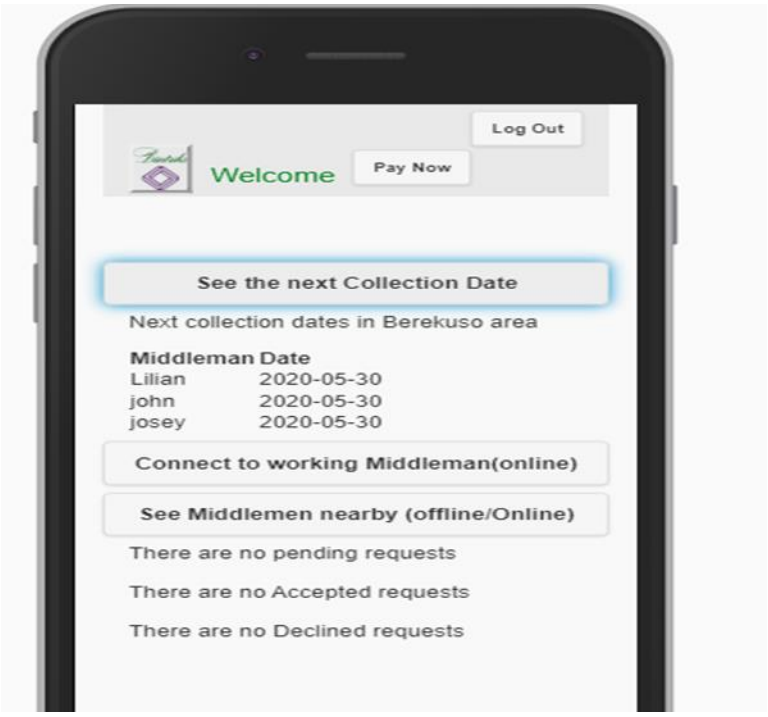

Figure 5.7: Homeowner see next collection date

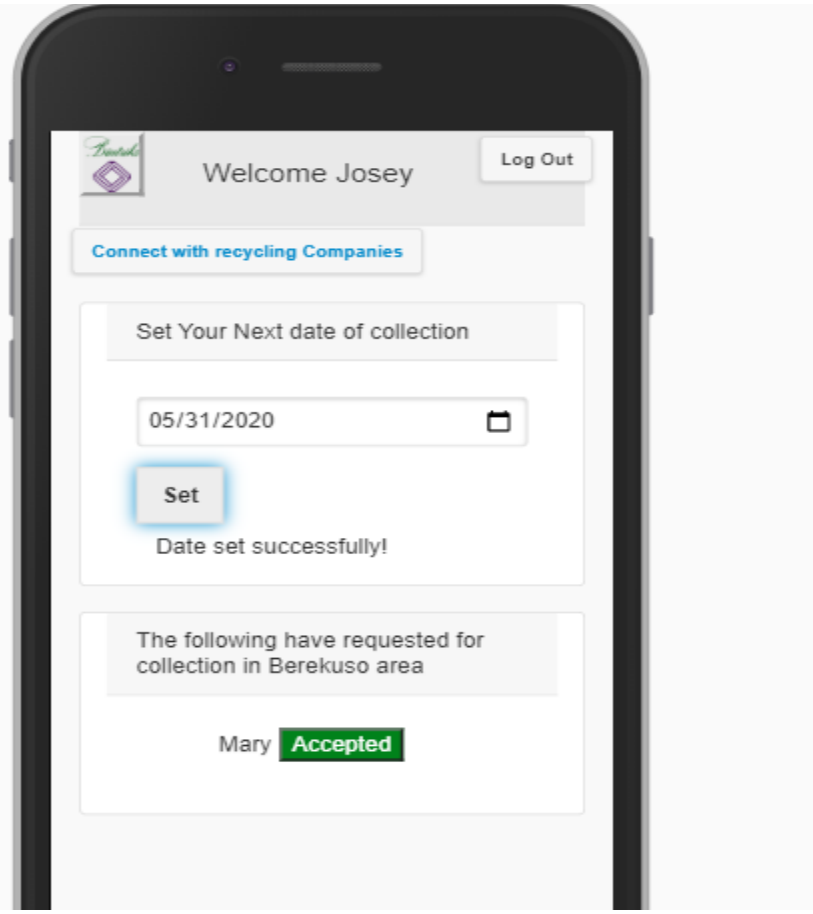

Figure 5.8: Middleman Homepage

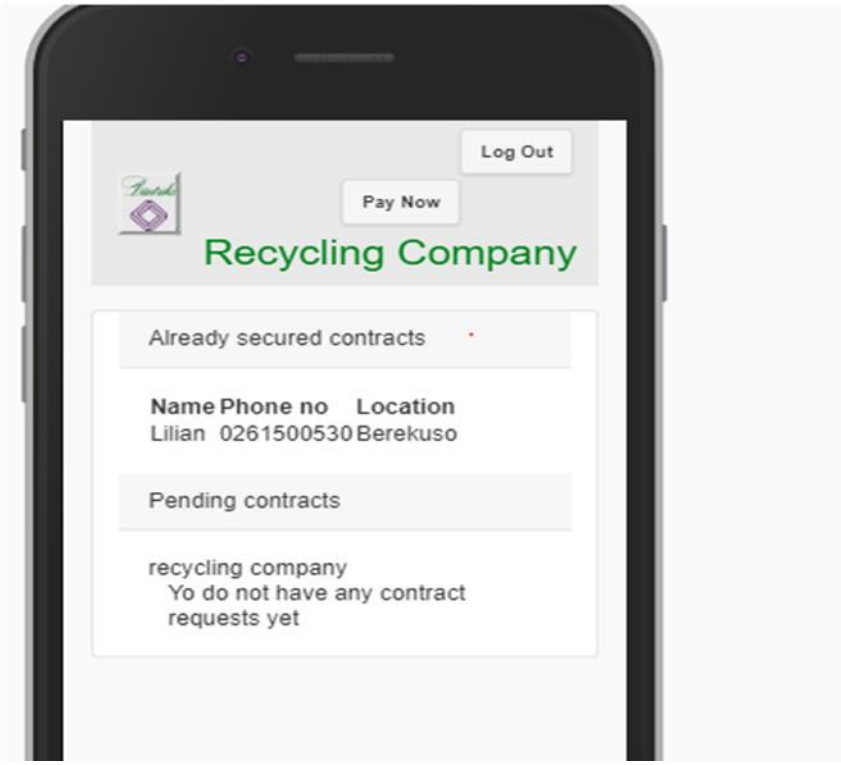

Figure 5.9 Recycling company Homepage

5.4 Back-end testing

Back-end testing was carried to make sure that the connection to the database was working, and that SQL queries issued to the database worked as expected. In this case, given the correct database credentials, the application was able to establish a connection with the database. SQL queries typed directly into XAMPP worked perfectly, which meant that manipulation of the data in the database was possible and working as needed hence also prove that the SQL commands would work when integrated with PHP in the application to query data from the database and edit it accordingly.

5.5 Install testing

This kind of testing was carried out to make sure that the applications generated by PhoneGap build were able to be installed to the different mobile phone types such as android, Windows 8 phone, and iOS-based mobile phones. The installation of the application in all the three platforms worked perfectly.

Chapter 6: Conclusion and Recommendation

This project is on developing a mobile application that is to be used to link householders and waste collectors for efficient waste delivery. The objectives of this project are: enable householders connect with waste collectors in real time to avoid delays and inconsistency in waste collection digitizing record keeping by keeping relevant details of users and their transactions in a database so that the data can be accessed at any time when needed and to also have a backup of data in case of any losses, enable users to use alternative means of payment such as use of mobile money instead of cash payment which is inconvenient, and also to ensure waste is recycled instead of being carelessly dumped by linking the middlemen who collect waste from homes to recycling companies who need that waste as raw material (mostly plastics).

Most of the initial requirements of this software, as outlined and discussed in sections 2.4 and 2.5 of this document, have been met. The requirements that have been met through the development of the application so far are:

- Users are able to create accounts
- Users are able to login into their existing accounts using the correct credentials.
- Householders are able to check for middlemen who are available in their location
- Householders are able to see middlemen around in real time and send requests for waste collection
- Middlemen are able to receive requests send by householders and accept or decline them
- Householders are able to get feedback as to whether their requests for waste collection have been accepted or declined.
- One collection is completed, householders are able to pay for services using mobile money.

- Householders and middlemen are able to confirm completion of task once waste has been collected.
- Householders are able to rate services provided by the waste collectors.
- Middlemen/waste collectors are able to award points to householders for sorting their waste accordingly for convenient collection.
- Recycling companies are able to secure contracts with middlemen

The requirements which have not been met are: Date prediction. The initial plan was for the application to give an estimate of the next possible date of collection. This would have required a lot of work and it would also not be efficient because the bola men may not necessarily show up on that date. Instead of this, the application makes it possible for waste collectors to state their next date of collection, which homeowners are able to see on their side.

Future Work

The usefulness and functionality of the mobile application developed in this project can be improved by implementing the following recommendations:

- Incorporating more means of payment such as use Paypal instead of only Mobile Money and credit cards.
- Including a feature that gives advice to householders on how to make waste that is not recyclable useful. For example, by using it for Do It Yourself (DIY) projects.
- By adding a chat/messaging and call feature within the application. This will increase convenience of using the application as users will not have to leave the application to text and/or message on other applications

- Having a USSD version of the application would also be very beneficial to users who do not have smartphones.
- Use of machine learning to study patterns of already collected data and predict the next possible date of waste collection in a given area.

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Appendices

Questionnaire Questions for Householders

Householders/residents questionnaire

* Required

Untitled Section

What means do you use to dispose waste at home?*

Your answer

If someone collects the waste, who is it?

- [ ] A middleman (bola man)
- [ ] A recycling company
- [ ] Other:

How frequently is the waste collected

Your answer

What waste is picked up?

- [ ] Metals
- [ ] Plastics
- [ ] Organic
- [ ] All (not sorted)

How much do you pay the people who collect the waste?

Your answer

What means of payment do you use?

- [ ] Cash
- [ ] credit card
- [ ] mobile money
- [ ] Other:

What means is used to keep record of collection and payments?

Your answer

Do you think the current disposal system is efficient? why or why not?

Your answer

What do you think can be done to make the system better?

Your answer

Would you use an application that links you to the bolar men/ recycling companies?

- ○ Yes
- ○ No
- ○ Maybe

Why would you use/ not use such an application?

Your answer

If such an application existed, what are some of the features you would wish to see in it?

Your answer

Questionnaire questions for Middlemen

Bola men/middlemen questionnaire

Untitled Section

How do you connect/communicatewith the households you work with?

Your answer

How frequently do you collect the waste from the households?

Your answer

What kind of waste do you collect?

- [ ] Plastics
- [ ] Metals
- [ ] organic
- [ ] All
- [ ] Other:

Where do you take the waste after collecting it?

Your answer

If the households pay you, how much do they normally pay for the services per one collection?

Your answer

What means of payment do you use?

- [ ] mobile money
- [ ] credit card
- [ ] cash
- [ ] Other:

What do you like about the current system of collecting waste?

Your answer

What do you not like about the current systemfor collecting waste?

Your answer

How different do you wish the system should be for it to be efficient?

Your answer

Do you work with any recycling company/companies?

- ○ Yes
- ○ No

If you work with any recycling companies, please list their names below.

Your answer

Do the recycling companies pay you?

- ○ Yes
- ○ No

Would you use an app that links you to households and recycling companies?

- ○ Yes
- ○ No
- ○ Maybe

Why would you use or not use the app?

Your answer

What are some of the features you would wish for such an application to have?

Your answer

Questionnaire Questions for Recycling companies

Questionnaire for recycling Companies

Untitled Section

What kind of waste do you recycle?

- ○ Plastics
- ○ Metals
- ○ Other:

How do you get the waste?

- ☐ Directly from households
- ☐ Through middlemen (bolar men)
- ☐ Other:

Do you pay the middlemen/households when they supply you with the waste?

- ○ Yes
- ○ No

What are some of the challenges you face in the process of acquiring waste to use as raw materials?

Your answer

How differently do you wish the system was from how it currently is?

Your answer

Would you use an application that linked you to households/middlemen?

- ○ Yes
- ○ No
- ○ Maybe

Why would you use or not use such an app?

Your answer

What are some of the features you would wish for such an application to have?

Your answer