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Mobile-based system for solid waste management to improve customer satisfaction and revenue generation: a case of Shinyanga municipal council

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MOBILE-BASED SYSTEM FOR SOLID WASTE MANAGEMENT TO IMPROVE CUSTOMER SATISFACTION AND REVENUE GENERATION: A CASE OF SHINYANGA MUNICIPAL COUNCIL

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A Project Report Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Embedded and Mobile Systems of the Nelson Mandela African Institution of Science and Technology

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ABSTRACT

Solid waste management has recently reached the top of the priority list in the modern world, but solid waste disposal practices are often neglected. In addition, managing municipal solid waste is one of the most challenging municipalities in Tanzania. Municipalities in Tanzania are responsible for the management of solid waste in their cities, but they have significant obstacles to providing a system that meets the needs of customers and improving revenue collection using the electronic payment system. This study determined the efficacy of solid waste management systems in Shinyanga municipality in customer dissatisfaction with waste collection service and unfriendly revenue collection. The objective of this study was to analyze the current waste collection system to determine the strength and weakness of the method used by solid waste generators and collectors to access the solid waste collection service, their willingness to pay for the service, municipal officials to manage revenues and complaints, and the participation of political leaders in offering cooperation. The analysis was to identify the requirements for the development and validation of the mobile-based system to improve customer satisfaction and increase revenue collection. The study used a mixed method approach, which included quantitative and qualitative data collection techniques to collect primary data with two sampling techniques, purposive sampling and multistage sampling. The developed mobile application adopted the evolutionary prototyping steps from the software development life cycle to implement all modules of the mobile application by allowing iteration of the development phases to ensure that user requirements are satisfied. The developed mobile based system was evaluated by the technical and end-user on the availability, scalability, user friendliness, consistency, navigation, feedback, performance, and security at both levels of. Although the results from the 10 ward areas indicate that 57% have access to solid waste collection services and collection is carried out daily at 31%, while two-thirds expressed dissatisfaction with the current waste collection system, the results after validating the developed mobile app show that the majority (85%) are willing to use the developed mobile app because it is useful to them since their negative emotions associated with solid waste collection were resolved, such as waiting for a waste collector for an extended period, paying informal waste collectors who increase waste collection costs, and being charged without receiving service, as they already felt overcharged. The study proposes a mobile application for solid waste management that will be used at and outside the Shinyanga Municipal Council for customer satisfaction and revenue growth.

DECLARATION

I, Stanley Isaac Manyonyi declares to the Senate of the Nelson Mandela African Institution of Science and Technology (NM-AIST) that this dissertation is my own original work and that it has neither been submitted nor presented for consideration of a similar degree award in any other university.

Stanley Isaac Manyonyi		03.08.2022
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The above declaration is confirmed by:

Dr. Silas Mirau		03.08.2022
Supervisor 1	Signature	Date

Dr. Mussa Ally		
Supervisor 2	Signature	Date

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CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by the Senate of the Nelson Mandela African Institution of Science and Technology, a Project Report titled "*Mobile Based System for Solid Waste Management to Improve Customer Satisfaction and Revenue Generation: A case of Shinyanga Municipal Council*" in Partial Fulfillment of the Requirements for the Award of the Degree of Master of Science in Embedded and Mobile Systems of the Nelson Mandela African Institution of Science and Technology.

Dr. Silas Mirau		03.08.2022
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DEDICATION

I dedicate this Project report to my parents and best friends; the late Mwalimu Charles Nyajirari Manyonyi and the late Mwalimu Dorica Kambura Munema, and my dearest family; Miriam, Jostan Abra, and Justice.

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LIST OF ABBREVIATIONS AND SYMBOLS

DBMS	Database Management System
HTTP	Secure Sockets Layer
HTTPS	Hypertext Transfer Protocol
ICT	Information and Communication Technology
IDE	Integrated Development Environment
iOS	iPhone Operating System
IoT	Internet of Things
JSON	JavaScript Object Notation
JSON	JavaScript Object Notation
LGAs	Local Government Authorities
LGRCIS	Local Government Revenue Collection Information System
MoEST	Ministry of Education, Science and Technology
MySQL	My Structured Query Language
NESR	National Environment Statistics Report
NGO	Non-Government Organization
PHP	Hypertext Preprocessor
PO-RALG	President Office-Regional Administration and Local Government
PPP	Public Private Partnership
SMC	Shinyanga Municipal Council
SSL	Hypertext Transfer Protocol Secure
URT	United Republic of Tanzania
WESS	Ward Environment and Sanitation Service
XML	Extensible Markup Language

CHAPTER ONE

INTRODUCTION

1.1 Background of the Problem

Waste management is a growing global environmental issue in developed and developing countries due to increased urbanization, rural-urban migration, rising living standards, and rapid development associated with population growth, which has resulted in increased solid and liquid waste generation by industrial, domestic and other activities (Moh & Abd, 2017; Nyampundu *et al.,* 2020; Orhorhoro & Oghoghorie, 2019). It is highlighted that 70-80% of the urban population lives without enough infrastructure and waste collection services, including improper solid waste collection systems (National Bureau of Statistics, 2017; Nyampundu *et al.,* 2020).

Not only does the National Bureau of Statistics (NBC) focus on increased solid and liquid waste generation and a lack of waste collection systems, but also other issues confronting solid waste management include a lack of enforcement of environmental rules and regulations and urban residents' refusal to pay for solid waste management services. While cities and municipalities, including Shinyanga Municipal Council, produce a growing amount of waste, the efficiency of their solid waste collection, segregation, transportation, treatment and disposal systems is decreasing.

In addition, in Tanzania an act requires local government authorities (LGAs) to manage and minimize solid waste under Sections 114 (1), 118, and 119 of the Tanzania's Environment Management Act (EMA) of 2004 which serves as the country's overarching environmental law under the establishment of the National Environment Management Council (URT, 2004). In addition, Shinyanga Municipal has by-laws that inform about proper waste disposal, penalties and fines for failing to follow environmental guidelines in the community. With the existence of this act and by-laws, they seem unhelpful in reducing complaints about solid waste collection services provided to residents of Shinyanga municipality. Residents in municipality areas are little aware of improved solid waste management in their community for the circular economy and to influence them to adopt a favorable attitude towards participation in controlling the increase in solid waste (Ezeudu & Ezeudu, 2019; Nyampundu *et al.,* 2020). Despite municipal regulations and bylaws that offer awareness, punishments and penalties for noncompliance with solid waste management, efforts to promote solid waste segregation have unsuccessful. This is likely due to the incapacity to access available opportunities and the lack of a mobile tool to spread awareness (Ballaran *et al.,* 2019).

A mobile application refers to application software with limited functions designed to operate on mobile devices which are movable, simple to use and accessible from any location such as smartphones and tablet computers (Islam & Mazumder, 2010; Li *et al.*, 2017; Phongtraychack & Dolgaya, 2018; Techopedia, 2020). Making mobile application requires the development of the application that plays an important role in business for earning revenue and meets the needs of users with various features such as low processing power, allowing users to download the application from various platforms like Google Play Store and iOS App Store, location detection, cost flexibility when using the application, and better network connectivity emphasized (Islam & Mazumder, 2010).

As a result of good network connectivity and Internet commercialization, Wang (2020) reported that marketing has been influenced by a variety of technologies, including electronic devices which permit interactions and mobile applications, have profoundly altered the way a company interacts with the clients by offering quick access to information about their products or services. Therefore, mobile application is not only for improving financial performance, but also for creating opportunities, strengthening client connections, and increasing client loyalty. The growing concept of mobile applications and devices is a step towards refining an efficient solid waste management process using enhanced and smart solutions. The mobile application for solid waste management is one of the smart solutions that can improve the efficiency of solid waste collection. This is based on significant cost savings, efficient use of resources, and increased productivity.

The developing world has challenging and irregular waste management systems that call for immediate action due to high growth rates, expanding urbanization and waste generation, weak government policies, a shortage of resources and a lack of awareness or willingness among stakeholders, low stakeholder environmental knowledge, and reluctance to accept new technologies have all been obstacles to a better and improved solid waste management system (Kumar *et al.*, 2017; Nagendra *et al.*, 2019; Shekdar, 2009). These negative indicators are the source of complaints, dissatisfaction with the provided service, and the little revenue collections experienced in the solid waste management system. The proposed mobile app innovatively can connect solid waste generators, solid waste collectors, and sanitation supervisors to collect and disseminate the solid waste information needed to promote satisfaction and revenue collection that results in meaningful social transformation (Paulos *et al.*, 2009).

The biggest drawback of manual-based solutions is the lack of privacy, security, and reliability of data due to an informal migrant going in the private and public areas collecting discarded food items, clothes, furniture, and appliance that appear to meet their demands or for sales. Although the

community stigmatizes scavengers because of the actions of some scavengers involved in stealing property, their activities are popular and increasing because they have the advantage of minimizing the transportation cost. Therefore, the mobile app is a tool that can be used by stakeholders, including scavengers, to provide and receive services electronically and formally, because it secures incoming and outgoing communication. Using the mobile app can reduce stigmatization and exploitation attached to scavengers, a situation that will reduce fear of the scavengers because they will also be registered in the formal waste management system and earn income in a participatory manner (Afon, 2012).

Technically, defining appropriate Android permission attributes for app components in the permission levels is to grant permissions to reduce risks on the privacy of the users by using their data responsibly and in accordance. Also, the permission levels used to protect the features that allow access to sensitive user data or device features for warning of sharing credentials and verification codes. In addition, the app will consider the security on network communication using network security configuration provided by the Android platform to solve the challenge of Hypertext Transfer Protocol (HTTP) which transmits information via untrusted in-between entities. The use of Hypertext Transfer Protocol Secure (HTTPS) with the Secure Sockets Layer (SSL) component will ensure that all information transmitted over the network is encrypted so that no hops can read it and integrated checks are performed on the information received. Therefore, we suggest that when users think a mobile-based system is secure, customers will be more motivated to keep using it since they will expect theft of their information will not occur (Wu *et al.*, 2020).

Given all the above-mentioned significance of mobile application, it relates to carefully eliciting all the requirements pertaining to the software application to develop the application which will serve the purpose of the intended users besides conformity to stipulated systems requirements.

1.2 Statement of the Problem

Shinyanga Municipal Council uses contracted community groups on behalf of the authority to collect solid waste in private, public, and commercial areas. Waste collection is carried out in a door-to-door operation style. Then, mixed solid waste from the house is transported to primary collection dumping sites. Solid waste collected is a mixture of plastics, glass, metal and food waste collected and transported by using wood carts and a three-wheeler motorcycle to create a favorable living environment.

With all the efforts in waste collection, storage, transportation and disposal, the municipal council

is suffering a problem of continually receiving complaints about access to the solid waste services irregularly, delays in accessing services, and an increase in defaulters because they are not satisfied with the service of collecting solid waste. Some complaints are that they stay for long time with uncollected waste that cause flood, insanitary condition, and unpleasant smell and become breeding places for germs and pests, which can cause diseases to human. These challenges have been the source of many municipal areas to remain polluted, waste collection stations are overloaded with solid waste, and the operation cost is greater than the revenue collected.

In addition, the rate of municipal waste production data is not available or gets repeated repeatedly, since the municipal management finds it difficult to keep track of the documents, information, and transactions. Before September 2020, unstructured waste data was stored in filing cabinets monitored by the Environment and Sanitation Service (WESS) Committee of each ward. There is possibility of missing the waste data for future use since data might get misplaced during manual filing, so data are not preserved properly for future use in planning, budgeting and reporting.

Although every household pays an amount of TZS 1000 an organic shop pays TZS 2000 a non-organic shop pays TZS 3000 a small hotel pays TZS 5000 and a large hotel pays TZS 10 000 Tanzanian shillings per month as the cost of collecting waste, taxpayers, waste collectors and municipal authority still complain to each other on charged without getting service, debts records, and no returns of commission to the waste collectors. An easy electronic payment system can quick and easy the process to ensure on-time payment and avoid potential late fees or service disruption to the taxpayers.

1.3 Rationale of the Project

The National Environment Statistics Report (NESR, 17) reported that in developing countries, solid waste management is considered one of the most serious environmental issues in most towns and cities. In addition, statistics show that 70 to 80% of the municipal population lives without infrastructure and solid waste collection service. With the increasing of urbanization, rural-urban migration, rising living standards, and rapid development associated with population growth, which have resulted in increased solid waste generation by industrial, domestic and other activities to support the manual-based system for managing solid waste for revenue generation and customer satisfaction. Using mobile based system is urgently needed for altering the way a company interacts with the clients by offering quick access to information about their products or services (Wang, 2020). Therefore, mobile application will assist the LGA not only in improving financial performance but also in creating opportunities, strengthening customer connections, satisfaction

and increasing loyalty. Here, there is a need to develop an effective mobile-based system for solid waste management to enhance revenue collection and improve customer satisfaction.

1.4 Project Objectives

1.4.1 Main Objective

The main objective of the study was to develop a mobile system for solid waste management to improve customer satisfaction and revenue collection at Shinyanga Municipal Council.

1.4.2 Specific Objectives

The following were the specific objectives addressed:

(i) To analyse the current waste collection system of Shinyanga Municipal Council.

(ii) To design and develop a mobile application for solid waste management.

(iii) To validate a mobile application for solid management.

1.5 Project Questions

By linking with specific objectives, the following research questions were answered to achieve the main objective of the study:

(i) What are the existing needs, gains, and pains in the current waste collection system for solid waste management?

(ii) What feature design are most important for developing a mobile-based system?

(iii) Does a mobile-based system developed have influence on solid waste management?

1.6 Significance of the Project

The solution of this study aims to provide effective and efficient service delivery to householders, solid waste collectors, and council official management through the provision of mobile application. The mobile application creates pain relievers for users of waste generators who seek the service, such as a quick booking of waste collection service by selecting the desired waste collector on the list of waste collectors. Our app will facilitate the registration of solid waste collectors approved by council officers, and then the app will display the list of solid waste collectors. This feature in our app will solve customer's pain like waiting for the service for a long

time.

Also, our app will provide a friendly payment option for consumers using their mobile devices without paying cash to waste collectors. In reality, limiting the use of third-party applications that access sensitive or private individual information is the safest option regarding client cybersecurity. Our mobile based system will consider that our mobile app user can access and pay the service using their mobile money systems without integrating with our solid waste mobile based system. This means that our app will not store or transfer the user's mobile money data to our app to access it. This approach will minimize the likelihood of user data being exposed to attackers. Our app will require the user to pay for the solid waste collection service using the mobile money menu by sending a notification message with the details of the payment account. Upon receipt of payment, the administrator of the waste collection system will log into the system and change the client's status.

Officials overseeing sanitation at council and ward level of Shinyanga Municipal Council (SMC) still use paper to keep records, making the solid management process more difficult, having confusing information and, even slower. This not only creates problems for waste collection operations, but also increases solid waste collection operational costs, delays in service delivery, and loss of information. Helped by the mobile-based system for solid waste collection, it will help eliminate paper use in handling various solid waste information including complaints from residents who have not received solid waste collection services in their areas. Through digital signature in our app, it will control the security of users' information and the privacy of their information, which in the paper system may lead to leakage of customer information.

The other advantage of the proposed mobile-based system is the ability to organize various reports such as resolved and unresolved complaints, solid waste collection, revenue collection and distribution reports simply for decision making.

1.7 Delineation of the Project

This study focused on revenue generation and customer satisfaction in the solid waste collection system using a mobile system from the Shinyanga Municipal Council. Also, the study considers android smartphone users because we want to develop a customized and needed solution, dealing with few bugs during development, spending less time on device and testing, the developer skill is on Java which is the tool and programming language adopted specifically for Android, and to save time and resources in the long term by providing a greater personalized experience, improving

performance and attractive app design to increase loyalty. The consideration on cross-platform development will be adapted when we want to increase the number of users of our app in other local government authorities in and out of Tanzania based on sharable codes, cost-effectiveness, wider audience, good network connectivity, internet commercialization, and mobile subscription, which shows that smartphone ownership is increasing rapidly in urban areas and people can afford the internet service offered by telecommunication and mobile operators.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Solid Waste Management

In both industrialized and emerging economy nations, waste management is a major environmental concern and has recently attracted many other scholars (Ezeudu & Ezeudu, 2019; Nyampundu *et al.,* 2020). Every living and non-living organism is affected by solid waste management, which is a worldwide problem, despite the promise of new ways to manage and reduce solid waste, the future of solid waste management remains uncertain (Moh & Manaf, 2017). Although the definition of solid waste management varies amongst research, researchers are most interested with innovative enabling technologies to make waste management operations more efficient, effective, and environmentally friendly. The Internet of Things (IoT), big data analytics, cloud computing, cyber-physical systems, and artificial intelligence are examples of innovative enabling technologies, although they are not limited to these. These measures can contribute to effective monitoring, collection, separation and transportation of waste to maximize value recovery and correct disposal while minimizing environmental impact (Zhang *et al.,* 2019). Furthermore, modern solid waste management solutions are still in its early stage due to the challenge that involves citizen behavior, product developers, manufacturers, authorities, infrastructure and operation related aspects (Aljerf, 2018; Fuss *et al.,* 2018; Zhang *et al.,* 2019).

2.2 State of Solid Waste Management in Tanzania

Although solid waste management services were provided free by the Tanzanian government, since the country's transformation to free market economics in the early 1990s, solid waste management services have increasingly been publicly owned and outsourced to the private sector. Approximately 12.1 to 17.4 million tons of municipal solid waste were reported to increase in the country each year (0.66–0.95 kg per capita per day). Waste generation in the country is increasing at a rate of 5% per year (Biswas & Singh, 2021). Households, businesses, and commercial locations, and institutions, markets, and street sweeping (Fig. 1), are among the main sources of solid waste (Biswas & Singh, 2021). Solid waste management is a critical issue that inhibits human and government activities. Any human can contribute to this problem by generating waste. Also, producing solid waste is one thing, but how that waste is processed or disposed of is another. Frequently, waste production exceeds the real ability to handle it. Residential, commercial, industrial and other sectors generate waste materials, and often waste treatment is entrusted to the government or administrative authorities (Patnaik & Mishra, 2021). The advantages of effective

solid waste management are vast; they can rescue entire communities from poverty and improve the economy of a country. In addition, it has been found that those who use their waste have a better chance of generating revenue and living a better life. Solving the solid waste problem will have implications that go far beyond what is better for the poor. In addition to environmental benefits, empowering citizens to take responsibility for their own waste disposal is an investment for the future. An understanding of how to effectively collect, treat, dispose of or reuse solid waste is needed to undertake initiatives to improve the situation (Ahsan *et al.*, 2014).

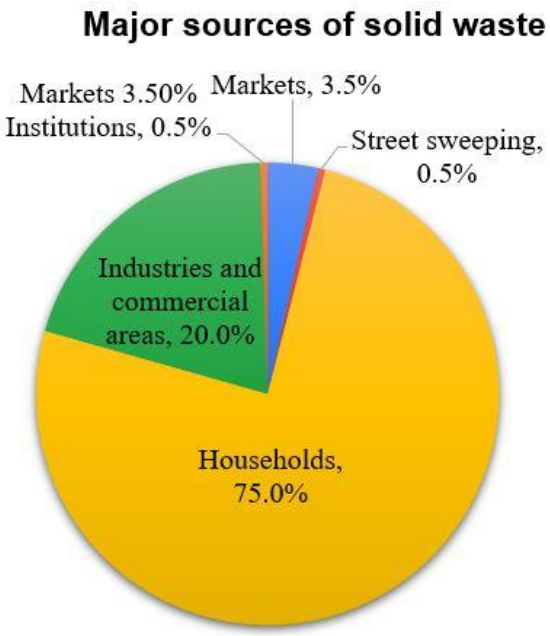

Figure 1: Major sources of solid waste

2.3 Mobile Based System for Solid Waste Management

Due to technological advances and innovations, stakeholders in industrialized countries are becoming more attentive to the problem of solid waste management. Due to high growth rates, rising population, solid waste generation, and a variety of waste characteristics in the developing world (and the lack of restrictive legal requirements), municipal waste systems have become increasingly challenging, which need corrective measures (Nagendra *et al.*, 2019; Shekdar, 2009; Troschinetz & Mihelcic, 2009). However, it has been difficult to improve municipal waste management systems due to poor responsibility, a lack of environmental awareness between stakeholder groups, and a lack of willingness to accept new technologies (Kumar *et al.*, 2017; Nagendra *et al.*, 2019; Sampaio *et al.*, 2017). A society can explore new ways by making sure that both the market forces and the service are actively involved in waste management. The study conducted by Nagendra *et al.* (2019) reported on the interactive society based on empowering

municipal residents, local councillors, and public workers that can act in growing urban issues by offering opportunities for them to engage, communicate, and voice their concerns through mobile technologies. These mobile technologies enable citizens to collect and share data to promote community action, which ultimately results in beneficial social transformation.

Purohit *et al.* (2016) showed that mobile governance is maturing to the widespread use of mobile networks in both urban and rural areas, to provide citizen services on mobile platforms because of the increase in the real-time data that are available and required for generating various reports. This advancement has enhanced the facilitation of a smooth transition from web-based electronic government services to more widely available mobile-based services. For example, many central government authorities and private sectors in Tanzania are already offering mobile government services in other sectors not related to solid waste management, such as local government revenue and tax collection, mobile health, mobile money, mobile banking, security, control system (Mwammenywa, 2018; Purohit *et al.*, 2016), and empowerment of entrepreneurs (Florian *et al.*, 2017).

As indicated by Ballaran *et al.* (2019), the generation of solid waste in the environment has increased considerably due to urbanization and rapid economic growth of the country. Households and areas with commercial and social activities have contributed to the generation of solid waste. The literature reveals that solid waste management services in cities and towns in lower-income and middle-income countries are outdated. This situation contributes to the development of poor cities and the livelihoods of poor people in these developing countries. Despite a challenging situation due to the crisis caused by solid waste generation, Nagendra *et al.* (2019) suggested the development of mobile applications to discover different issues affecting the solid waste collection system. Local government officials, citizens, and other stakeholders can use the built application to discover it as meaningful infrastructure to solve everyday problems because the use of mobile application technology for the management of solid waste has shown positive prospects.

Additionally, the study conducted by Tang (2019) reported that for organizations, smartphone apps have reshaped customer behavior by allowing people to engage in activities such as entertainment and information exchange, but they have also revolutionized the way organizations brand and promote their products and services. When customer behavior has changed due to improved residential solid waste management, they are motivated to pay for a better waste collection service in their own homes (Patnaik & Mishra, 2021). Although numerous mobile-based solutions have shown good results in the waste management sector, few studies have been conducted on how mobile applications can improve customer satisfaction and generate revenue in SMC.

So far, SMC as a town in a developing country is experiencing an outdated framework in solid waste management. According to information by National Bureau of Statistics (2017), shows that the primary goal of solid waste management is to minimize and eliminate the negative effects of solid waste on human health while also promoting economic and social development. Not only promoting socioeconomic development, but also creating quality life by making the environment a safer place for both living and non-living things. However, the current solid waste management process has many challenges, such as inefficient use of resources used, high operating costs, not being implemented bylaws, and increasing complaints from all stakeholders. This can lead to waiting a long time for a service, being charged without getting service, meeting with unsafe waste scavengers, loss of revenue, and wrong information (Nkurira, 2021).

Furthermore, despite the efforts made in cities, municipalities and towns in Tanzania, the literature does not indicate the use of a mobile application that helps the management of solid waste from waste generation, handling, storage and processing on site, waste collection, waste transfer, and waste processing recovery (National Bureau of Statistics, 2017). But there is a mobile application called Local Government Revenue Collection Information System (LGRCIS) Mobile app version used to issue payment receipts for each transaction in every source of revenues. This makes the mobile application unfriendly to home owners, waste collectors, health and sanitation officers, and other stakeholders. Mobile applications are another new trend in the digital world with the focus on mobile data security, privacy and reliability. This innovative concept for mobile application is used to overcome the shortcomings of the outdated waste management and mobile application solutions mentioned above. The goal of the proposed solution is to enable users to systematically request waste collection services, provide a friendly payment system, retrieve waste information, and monitor community participation in solid waste management, such as solid waste collected, revenue collected, and to address comments or complaints promptly.

2.4 Related Work

Using the mobile-based system, studies have been looking into modern and friendly solid waste management. The improvement of waste management systems to promote customer satisfaction and revenue collection has been a recent topic in sustainable solid waste management.

In the study conducted by Ballaran *et al.* (2019), recommends the use of a mobile application is recommended to support solid waste management activities in the city of Barangay, Philippines. Because of this research, the mobile application called *Perazuhan* was developed to promote people to sell only recyclable materials such as bottles, newspapers, and plastics to junk shops. Although the mobile app has enabled regulating the seller of recyclable materials with buyers and having a calculator to show the revenue after the sale, the system is incapable of allowing payments and cannot request for the collection of a non-recyclable.

Nagendra *et al.* (2019) presented a mobile application to track municipal waste to citizens, councilors and public servants in Bangalore city. The mobile waste tracker made it easier for residents to complain about cleanliness. Additionally, a mobile application that automatically detected uncollected waste in geographical locations. The information is then uploaded to a cloud server after being registered as a complaint with a location on the mobile app. Finally, a dashboard visualization will be used to collect all complaints before sending them to the ward councilors, who ensure that waste is collected based on the information given. However, the system does not offer a means of payment for the solid waste collection service in the residential and commercial sectors.

To increase customer satisfaction and revenue collection, this study aims to develop a helpful, usable and protected mobile-based system that includes immediate service requests, the ability to choose a solid waste collection and a friendly electronic information and payment tool. The proposed mobile-based system adds new elements to adopt the Tanzanian context while incorporating common aspects discovered in other studies. The mobile-based system can be accessed online that the solid waste generators, waste collectors, and municipal officers can use it to access and provide the solid waste service.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the Study Area

Data from this study were collected between July and August 2021 from ten wards, namely: Ibadakuli, Ibinzamata, Kambarage, Kitangili, Lubaga, Mjini, Chamaguha, Ndala, Ndembezi and Ngokolo, in Shinyanga Municipal Council. Data collected were demographic characteristics, awareness and attitude, barriers, and the desired future for solid waste management (Fig. 2). The listed wards were chosen based on the prevalence of solid waste management, such as wards with a solid waste collection schedule, qualified to be mixed or urban, high and medium solid waste generation, and high percentage of populations.

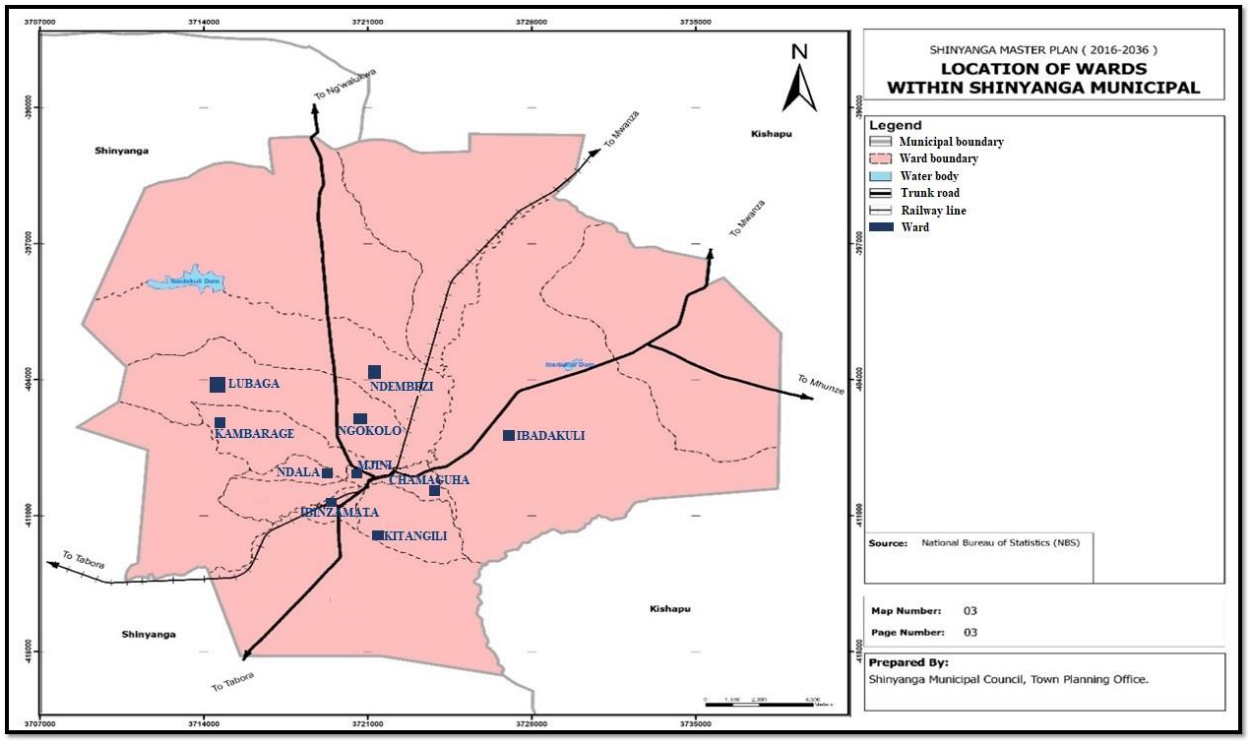

Figure 2: Map of Shinyanga Municipality showing the study area

3.2 Research Design and Data Collection

To achieve the objective of this study, questionnaires, interview and observation checklist were used to gather primary data, while a solid waste revenue collection report from the local Government Revenue Collection Information System was used to gather secondary data. The study comprises (1) households to assess access to the solid waste collection service, (2) the willingness of waste generators to pay for the service, (3) municipal officials to manage revenue and complaints, and (4) the participation of political leaders to offer cooperation to the solid waste

collection system. Therefore, the multistage sampling process was involved by choosing ten wards in Shinyanga Municipal Council using simple random sampling. Then, one street was chosen within each selected ward using the systematic sampling method. Finally, five households were selected from each street using simple random sampling. Besides sampling approach, we determined a sample size based on the ability to reliably quantify a feature shared by 5% of the population size of 1240 households found in Mjini ward. The final decision was influenced by factors such as budget and time availability. The study used four categories of stakeholders involved in solid waste management due to their responsibilities. The groups are: The first group was fifty households from 10 wards. The second group consisted of three politicians, one was the councilor who is the representative of the Ndembezi ward and municipal mayor, and two were chairmen representing local governments of Mitimirefu street in the Mjini ward and Jomu street in the Kambarage ward. The third group is the five solid waste collectors responsible for picking up the solid waste from the household, commercial, and institutional places. Waste collectors are also responsible for taking collected solid waste to the primary solid waste disposal facilities known as 'maghuba' for short storage before being collected by municipal vehicles to the main municipal landfill site. This dumping site is 15 kilometers from the municipal headquarters. The last fourth group who responded to this study was 2 municipal officials in charge of all matters related to waste management. The percentage of respondents for each gender participate by their ward location and the number of respondents broken by title and location is shown in Fig. 3 and Table 1.

The tableau platform and Python programming language were used to analyze the statistical data entered into the excel formatted file to generate data visualizations. The SMC authority provided ethical clearance, and the municipal sanitation and health officer at the SMC granted permission to conduct the study, which was presented to solid waste collectors and local government officers. Before the data collection process began, participants were asked to volunteer to participate in a study. Participants received a written or oral statement that stated the purpose of the study and the use, limits, and privacy of their personal details.

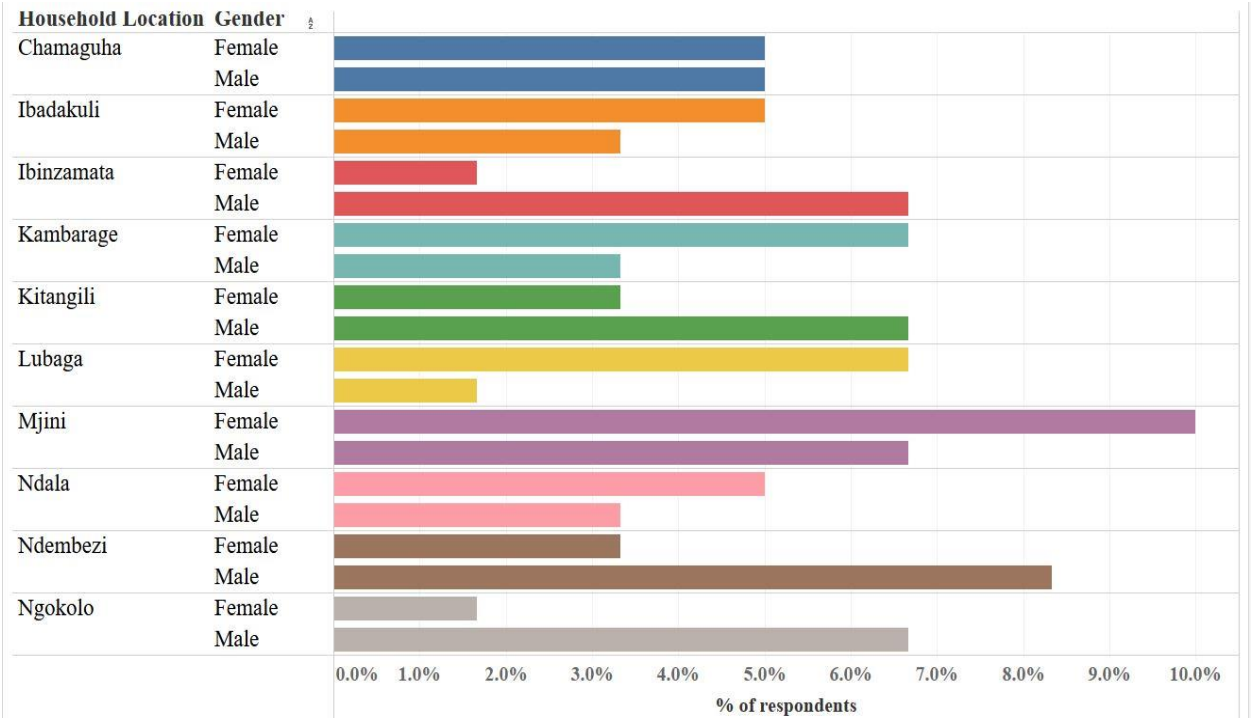

Figure 3: The percentage of respondents for each gender participate by their ward location

Table 1: Number of respondents broken by title and location

Title	Location	Number of respondents
Councilor	Ndembezi	1
Environment health officer	Mjini	2
Household	Chamaguha	5
	Ibadakuli	5
	Ibinzamata	5
	Kambarage	4
	Kitangili	5
	Lubaga	5
	Mjini	6
	Ndala	5
	Ndembezi	5
	Ngokolo	5
Local government chairperson	Kambarage	1
	Mjini	1
Waste collector	Chamaguha	1
	Kambarage	1
	Kitangili	1
	Mjini	1
	Ndembezi	1
Total		**60**

3.3 Evolutionary Prototyping Methodology

Faster and better systems are being developed more quickly and at a reduced cost aided by iterative development (Pawar, 2015). Due to this technique, it is possible to provide stepwise outputs.

Prototyping enables non-linear development of the system. While doing a preliminary research, developers create a functional prototype of the system and present it to users for feedback. Repeated iterations are necessary to satisfy users (Patrice, 2020). Furthermore, Carter *et al.* (2001) reported that the goal of evolutionary prototyping is to collect a true and reliable number of needs. By clarifying current needs and finding new unexplored or unrecognized requirements, the methodology ensures that acceptable applications are built. Due to the potential for demand expansion and the difficulties of addressing it, linear reassessment of system requirements has not been the cure that developers have expected. Requirement identification and clarity are aided by these approaches, which help prevent requirements displacement. To assist the efficient development of mobile applications, the model is now being validated in many software development activities (Kordon & Luqi, 2002). In this study, the proposed fast, accurate, and efficient mobile app development model is depicted in Fig. 4.

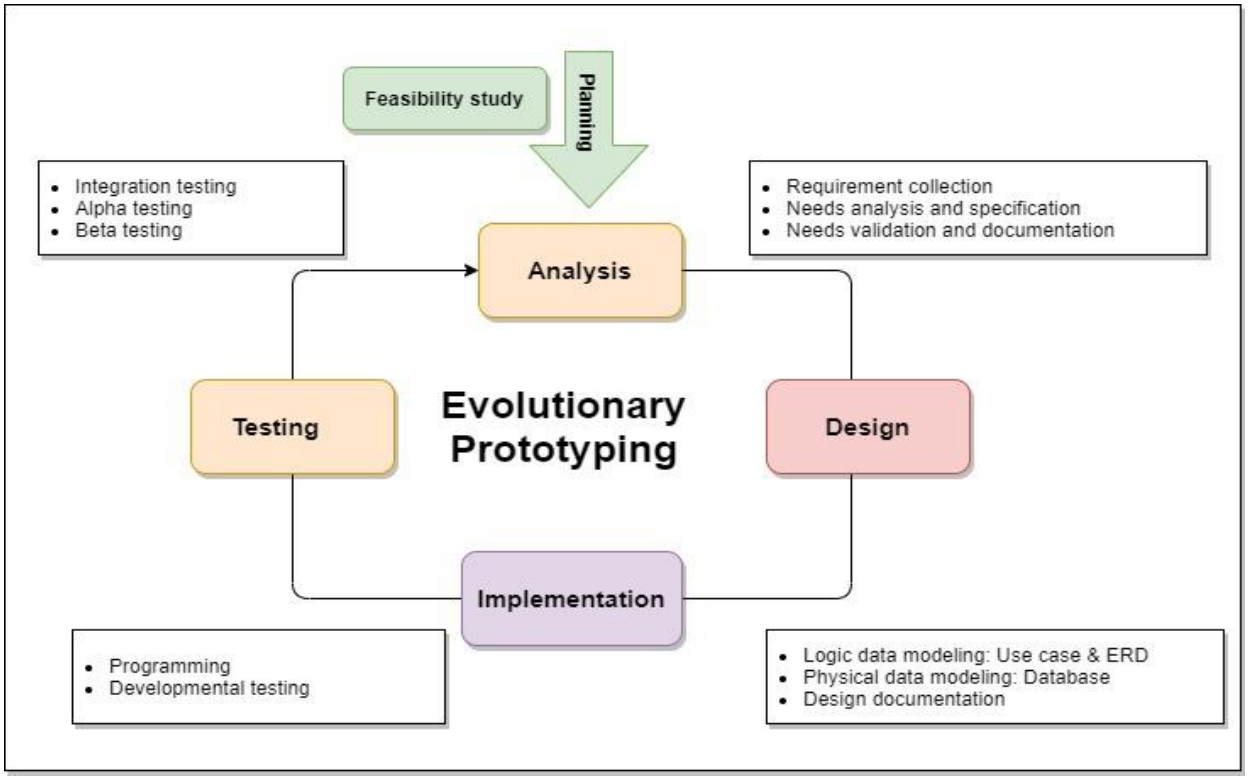

Figure 4: Evolutionary Prototyping model for developing mobile application

3.4 Mobile App Development Approach

This study employed a mixed method approach, which included both quantitative and qualitative data collection techniques to collect primary data (Dudovskiy, 2021). Linking qualitative and quantitative components tries to establish connections between them to accomplish the following: (a) Merging the two data sets, (b) Connecting the analysis of one set of data to the collection of another set of data, (c) Combining one type of data within a larger procedure, and (d) Using a

framework to connect the data sets (Schoonenboom & Johnson, 2017). The mobile application was built using the fundamentals of software engineering. The steps of evolution prototyping adopted from the Software Development Life Circle were used as shown in Fig. 1 to implement all modules of the system. This adoption was used to obtain input from intended users to refine the built mobile application. The goal was to develop a valid version of the system and then offer users with assessment and support on the final product. Subsequently, the mobile application was refined in response to user response and refinement. The updated mobile application was returned to the intended users for further testing, and the process was repeated until the users were satisfied with the final product. The mobile based system development approach was divided into four phases, which are:

3.4.1 System Analysis Process

To begin the design process after developing a preliminary project plan, it is necessary to start with the identification and collection of the basic requirements. These basic requirements include both input and output information such as users of the system, all necessary steps, activities, and goals of using the system. Two categories of requirements are: (a) functional requirements which specify what the mobile application can perform (Table 6), and (b) non-functional requirements which describe the quality attributes or constraints of the application to address a variety of challenges, including performance, operation, user-friendliness interface, economic and maintainability (Table).

3.4.2 System Design Process

The second phase is the system design, which involves conceptual and physical design. The conceptual design expresses and evaluates possible solutions and is completed in partnership with users, whereas the physical design focuses on the logical and physical schema of the actual database.

3.4.3 System Implementation Process

The third phase was to develop a mobile-based application that allows users to interact with it. During this phase, we built a mobile application by using functional and non-functional requirements, conceptual and physical design. This phase was implemented incrementally that included system development and system testing until we met the needs of the users. The tools and technology used to develop the mobile based application are: (a) Android studio which is an Integrated Development Environment (IDE) that based on IntelliJ IDEA, a Java integrated

development environment for software development that includes code editing and developer tools for Android application development within the Android Operating System. Android is one of the most powerful and adaptable open-source systems for smartphones, tablets, smart television, and other mobile devices, (b) The XAMPP which is an open source mostly used as a web server, it stands for cross-platform, APACHE, MariaDB, Hypertext Preprocessor (PHP) and Perl, (c) The MySQL, an open source used for database design and management. The study used MySQL due to its reliability, high performance, scalability and defined role-based access control Database Management System (DBMS) that uses standard Structured Query Language (SQL) to meet user demand, (d) JavaScript Object Notation (JSON) is the exchange technology used to allow the developed mobile application to communicate with the remote Web server with the data, (e) Extensible Markup Language (XML) in this study was used for creating primary user interfaces (Appendix 5), (f) Firebase is the technology used in developing messaging and crash reporting system in the mobile application, and (g) Java as the language used to implement the business logic of the mobile application following the completion of user interface design (Appendix 6). The selection of Java language is because it comes with pre-packages with numerous libraries in the Android IDE.

3.4.4 System Testing Process

The fourth phase was to test and evaluate the final mobile application. The final mobile application was tested and evaluated to ensure that it met expectations. In each iteration, we followed system integration testing performed by the programmer, alpha testing which was performed by the internal and external system tester to find bugs before releasing the application to the end users, and finally the beta testing was conducted by the end users of the developed application in a real environment setting. Every step of this phase included the input of end users. This was done to ensure that the system considers the user's context and requirements.

3.5 Evaluation of Mobile-Based Application

3.5.1 Technical Evaluation

Thirteen systems development professionals from Shinyanga MC, Kahama MC, Shinyanga DC, Msalala DC, Ushetu DC, Kishapu DC, and NM-AIST were asked to evaluate this mobile application on a technical level. They were specifically requested to assess the *Zoataka* app in terms of availability, scalability, friendliness (usability), consistency, navigation (connectivity), feedback, performance, and security. The technical team was asked to score each of the offered characteristics

on a scale of Very High, High, Average, Low, or Very Low by checking one box and justifying rates below Average (Appendix 3). To facilitate graphical presentation, the number of evaluators was transformed to a percentage.

3.5.2 End-User Evaluation

During the identification of factors that contribute to the mismanagement of solid waste and the dissatisfaction of the solid waste collection system, similar stakeholders (household, waste collectors, municipal officials and political leaders from the Mjini and Ngokolo ward) were invited to provide feedback on the evaluation of the developed mobile application. Within this situation, these factors were considered: (a) Ability of the mobile application to approve workflows and authorization levels (business requirements), (b) The ability of the routine things the system is doing, such as reporting (administrative functions), (c) The ability of the mobile application to allow the user of the system to place a solid waste collection order or browse the online list of waste collectors (user requirements), (d) The ability of the application to function in the users handset such as operating system and hardware specifications and system responses (system requirements), (e) Clarity of the output of the mobile application, (f) Usefulness and helpful of the mobile application, (g) The need of support and technical assistance in using this mobile application, (h) Internet connectivity works perfectly with the mobile app, and (i) Willingness to use the app and recommendation to others. End users were requested to rate each of the presented aspects on a scale of Very High, High, Average, Low, or Very Low (Appendix 3).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

4.1.1 Current Solid Waste Collection System

Shinyanga Municipal Council uses various methods to collect municipal solid waste. These methods are:

(i) Self-Solid Waste Collection

Solid waste generators either deliver solid waste directly to the primary dumping site or contract unofficial waste collectors (Fig. 5).

(ii) Public Bin Collection

Customers dispose of their solid waste in public bins strategically placed around the municipality. Regularly, waste collectors collect solid waste found in public bins (Fig. 6).

(iii) House-to-House Collection

This method is used by contracted waste collectors to visit each house to collect solid waste. The solid waste collection service is usually charged monthly to the customer. In this method, customers must place their solid waste directly outside of their home (Fig. 7).

In SMC, the most popular solid waste collection method is house-to-house, whereby the residents place their solid waste in plastic bags, plastic buckets, or other containers outside their house for solid waste collectors to collect and transfer it to temporary dumping sites. Municipal solid waste is in the residual class which contains single-family or multifamily in the same house; the commercial class that includes markets, hotels, restaurants and shops; the institutional class has schools, hospitals, and government buildings. The industrial class includes small, medium, and heavy production facilities. Waste collectors uses wood-made wheelbarrows, three-wheeled motorcycles, and solid waste cars to transfer collected solid waste from the residential, commercial. Institutional and industrial areas to the dump sites (Fig. 7).

Figure 6: Primary dumping site at Majengo ward

Figure 5: Public bin positioned at Kitangiri ward

.

Figure 7: Waste collectors uses wood-made wheelbarrows and tippers to collect door to door solid waste

4.1.2 Sociodemographic Characteristics

Sixty people were planned to participate in this study, 63 people responded to questionnaires and interview questions from ten wards of SMC, giving an overall response rate of 105%. Table 2 shows sociodemographic characteristics where 55.56% (35/62) of the participants were male, and 84.12% (53/63) identified as participants with an income of more than TZS 50 000 monthly, and the majority, 57.14% (36 /63) were in the self-employment system. These two characteristics; income and employment status, indicate that two-thirds of the respondents can afford to pay the solid waste service fee monthly because it costs the minimum of TZS 1000 per month per household. The 46.03% (29/63) of the participants had completed their college education, and 57.14% (36/63) were between the ages of 21 and 40. The findings reveal that half of the respondents were young adults between the age of 21 and 40 who are strong to learn and can have a good attitude towards the use of proposed mobile systems. The 84.12% (53/63) of the respondents in this study have a residence for more than 5 years where the population in the participating households has a number of more than two occupants, which is equivalent to 90.47% (57/63).

Table 2: Sociodemographic characteristics of the participants

Characteristics	Frequency (n = 63)	Percentage (%)
Gender (Sex)		
Male	35	55.56
Female	28	44.44
Age in years		
21-40	36	57.14
41-60	22	34.92
Above 60	5	7.94
Level of education		
Primary education	10	15.87
Secondary education	24	38.10
College education	29	46.03
Employment status		
Self employed	36	57.14
Employed for wages	25	39.68
Retired	2	3.17
Monthly income status in Tanzania shillings		
0-50 000	10	15.87
50 001-100 000	15	23.81
100 001-150 000	2	3.17
150 001-200 000	4	6.36
More than 200 000	32	50.79
Duration of households in years		
0-4	10	15.87
5-10	25	39.68
Above 10	28	44.45
Household occupants		
1	6	9.53
2-4	43	68.25
More than 4	14	22.22

These results show that, rather than implementing manual processes that promote mistrust among residents who do not have the characteristics of migrating their households away from Shinyanga Municipality, a mobile-based system is needed for them to develop a feasible solution for solid waste collection. This means they are not migratory residents, so they are residents who will continue using the mobile-based system for a long time. Smartphone ownership was found in 92.06% of the households (58/63) studied, with the 80% of this smartphone ownership being using Android kind of operating system. Neither Android nor iPhone has appeared twice with different statistics because 1.5% (1/63) of the respondents replied that they own a smartphone that is not an Android and not an iPhone. There are also 6.3% (4/63) of the respondents who responded that they do not have a smartphone, meaning that they have a featured phone (Fig. 8). These findings reveal that developing a mobile-based system that works on android phones will be the right technology that will connect many users with extensive experience in using android phones before switching to a cross-platform development approach to accommodate the increasing size of users, developer skill, performance, and design issues.

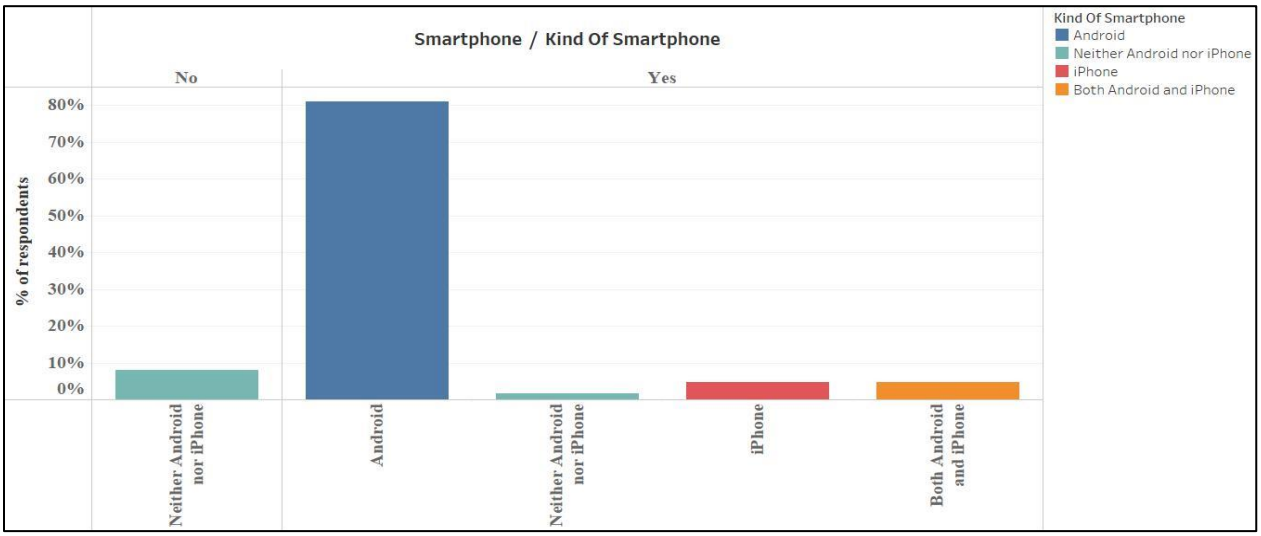

Figure 8: Percentage of respondents for each kind of smartphone broken by smartphone ownership

4.1.3 Practice in Solid Waste Management

The availability of the solid waste collection service was found in 57.14% of the respondents studied where the frequency of collecting solid waste by solid waste collectors daily is 31.75% (Fig. 9).

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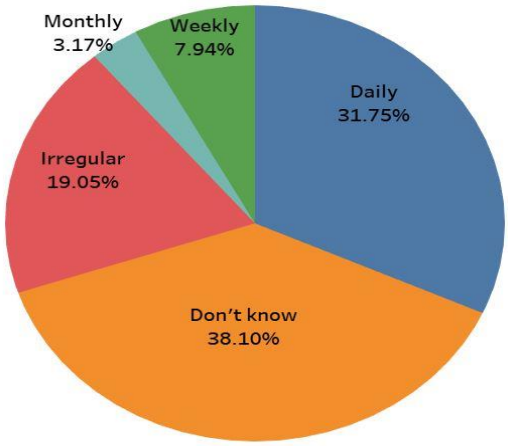
Figure 9: Frequency of Solid Waste Collection by Waste Collectors



The 49.21% of lifestyle-related activities that generate solid waste are: (a) Cooking and eating habit, (b) Daily inside and outside cleaning routine with the composition of food, papers, plastics, glasses, electrical and electronic waste, and (c) Food related formal and informal business activities such as selling food, vegetables and fruits (Table 3). These statistics show that every day there is waste generation that does not match the pace of waste collection, as two-thirds of respondents do not receive daily waste collection services. Only 3.17% of the respondents were very satisfied with the service and the majority of the respondents (92.06%) will pay the waste collection fee (Table 4). The findings show a positive correlation between education level and willingness to pay for better solid waste collection services. Therefore, as individual education advances, the willingness to pay for better solid waste collection services increases. This outcome is comparable to Patnaik and Mishra (2021). So, the proposed app is the right tool to motivate waste collectors to deliver the service daily on time.

Table 3: Practice of participants in solid waste management

Practice	Frequency (n=63)	Percentage
Availability of a solid waste collection service		
Yes	36	57.14
No	27	42.86
Lifestyle-related activities that generate solid waste		
Cooking and eating habits	31	49.21
Daily indoor and outdoor cleaning routine	21	33.33
Food-related informal business activities such as selling food, vegetables, and fruits	11	17.46

Table 4: Percentage of respondents broken down by willingness to pay the waste collection fee and satisfaction status with the waste collection service vs. level of education

Level of education	Willingness to pay for the service	Satisfaction status with the waste collection service			
		Not satisfied	Less satisfied	Very satisfied	Total
College education	No	3.17			3.17
	Yes	19.05	20.63	3.17	42.86
Secondary education	No	1.59	1.59		3.17
	Yes	11.11	1.59		12.70
Primary education	No	1.59			1.59
	Yes	30.16	6.35		36.51
Total		66.67	30.16	3.17	100

Solid waste is most commonly transported from the collection point to the dump site by placing outside the place the collection sac (57.14%) such as boxes, plastic bags and plastic buckets carrying over the head to the dump site (33.33%), while 9.52% of the respondents have waste pit at home where the method used to dispose of their generated solid waste includes burring and burning (Table 5). Only 19% of the total revenue collected from this revenue source was deposited in the council account (Fig. 10). This indicates that there are other expenditures being made outside the corrected system of using collected revenue, and creates unnecessary defaults. The 6.35% of the respondents sent complaints about the solid waste collection service to the authority by telephone call (Fig. 11). These findings reveal that a large population wastes time to submit a complaint to the municipal office or fails to arrive at the municipal office due to the physical distance to reach the officials responsible for resolving the complaint. The study finds that there is a need of using a mobile based system which can help anyone to send the complaints anywhere and anytime. The solid waste collection service is irregular, the low frequency of the service, and improper waste collection are the main reasons for the dissatisfaction with the service felt by 66.67% of the respondents (Fig. 12).

Table 5: Percentage of respondents broken down by points of solid waste collection and methods of disposing solid waste

Points of solid waste collection	Methods of disposing solid waste	Percentage
Carrying to the collection point	Illegal dumping	9.52
	Open dumping	23.81
Placing outside	Boxes	7.94
	Plastic bags	33.33
	Plastic buckets	14.29
	Give to recycling	1.59
Home waste pit	Burning	4.76
	Burying	4.76

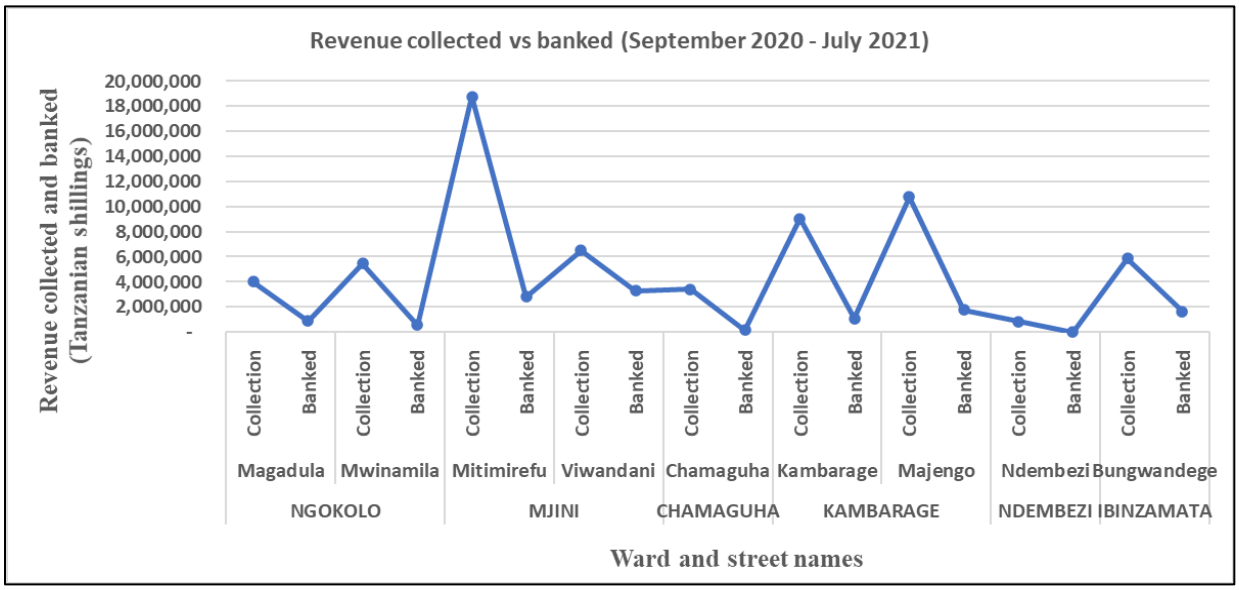


Figure 10: Revenue collected vs banked by 6 solid waste collection groups

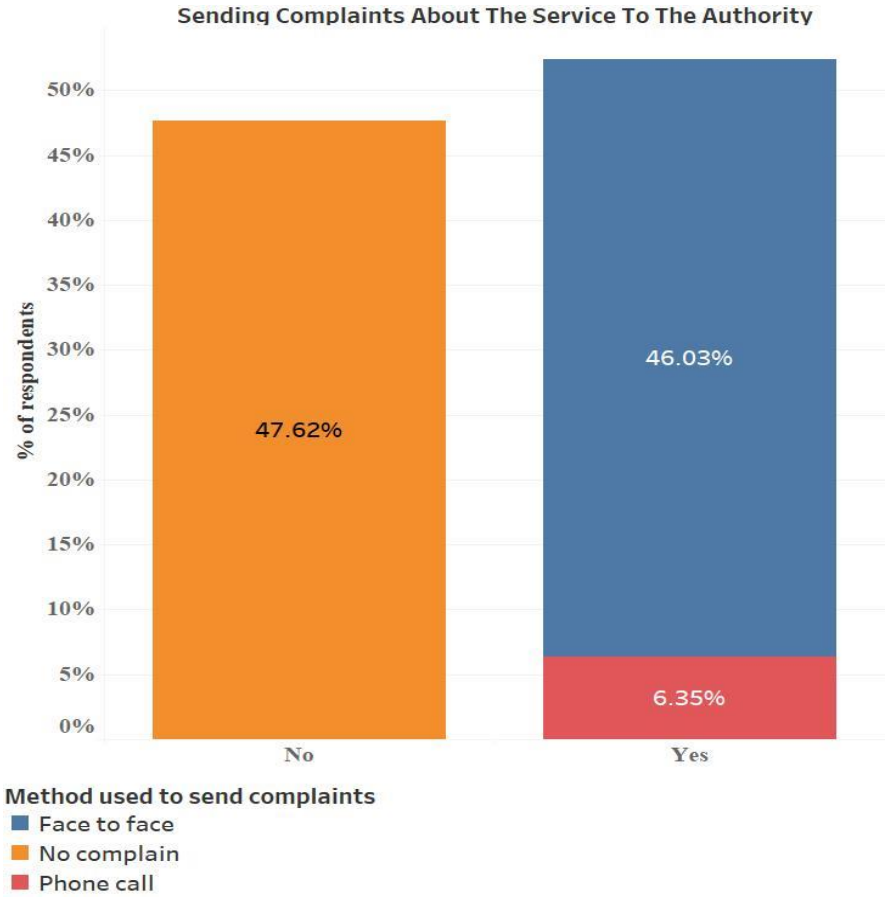


Figure 11: Percentage of respondents of sending complaints and methods used to send complaints about the solid waste to the authority

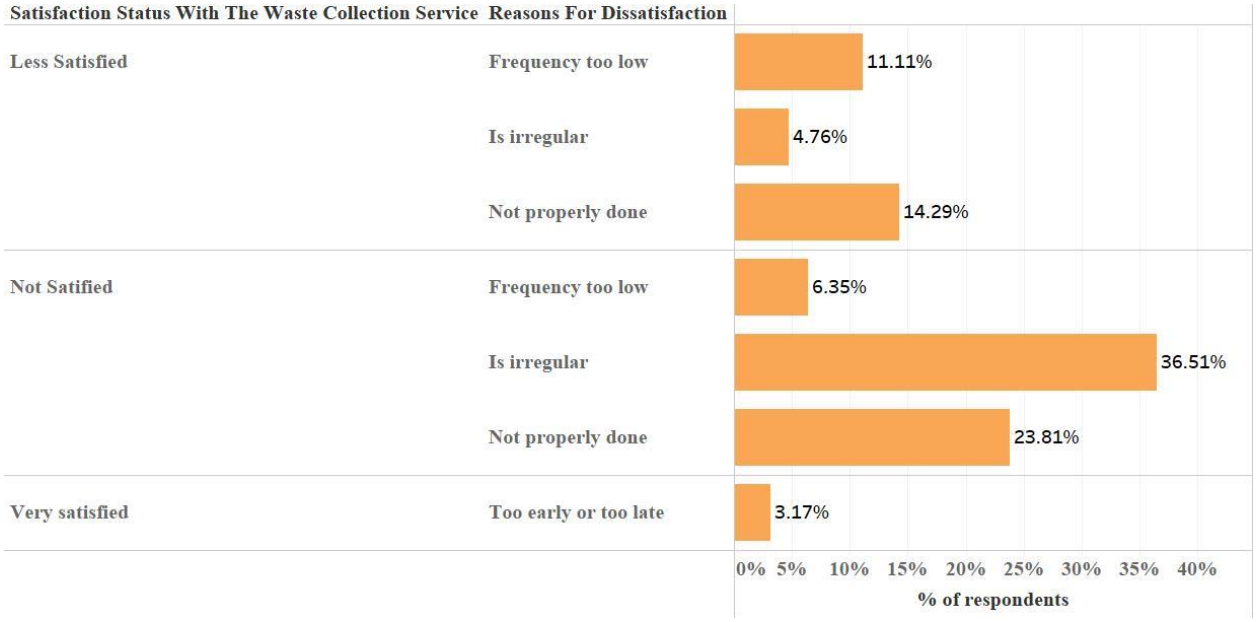


Figure 12: Percentage of respondents for each reason for dissatisfaction broken down by satisfaction status with the solid waste collection service

4.1.4 Desire Expected in the Collection of Solid Waste

The majority of respondents (57.14%) to the questionnaires and interview indicated the desire to have solid waste collectors capable of arriving on time in solid waste collection. In addition, 12.70% of the people who participated in the survey in this study showed interest in obtaining the service of waste collection from professional solid waste collectors. While 9.52% of the respondents needed a friendly and easy payment system, 7.94% indicated that the system needed to allow users to view current and updated solid waste information (Fig. 13). These findings reveal that citizens do the jobs that create income for them. This indicates that the challenge in the solid waste collection system is not about the lack of money to pay for services. So, if citizens are educated on solid waste management, they can afford to pay for services. The proposed mobile-based system will be a tool for educating and informing the community on various benefits of collecting solid wastes.

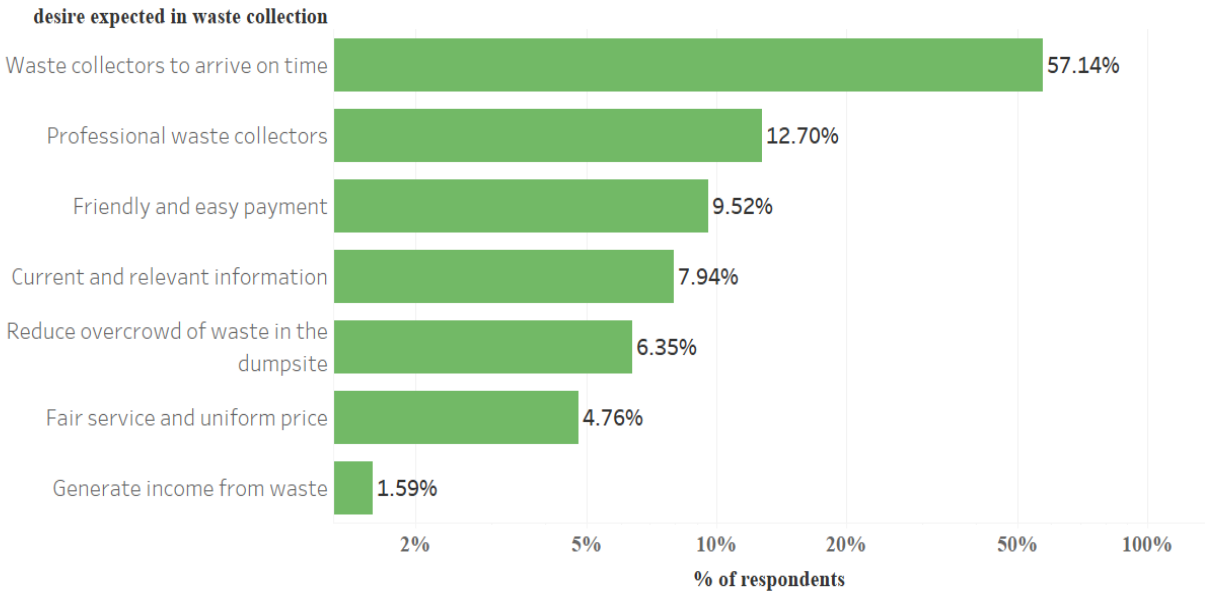


Figure 13: Percentage of respondents for each desire expected in solid waste collection

4.1.5 Requirements for the Proposed Mobile-based System

Two categories of requirements for the proposed mobile-based system are functional requirements that specify what the mobile application can perform and nonfunctional requirements that describe the quality attributes of the application to address a variety of challenges, as summarized in Table 6 and 7.

Table 6: User roles and system functionalities

User	Roles
Municipal official	Manage users (update payment status, send payment alert, and delete) Manages waste collectors (approve, reject and delete) Manage complaints Manage news for visualization (adding news, deleting old news) View revenue collection and distribution reports (council, wards, street, and collectors) View usage reports (total customers, total collectors, and waste collected)
Waste Collectors	View service requests from the users (new, pending, and completed) Create bills Send complaints View individual revenue allocation (collect solid waste)
User	View list of waste collectors Send a service request Send complaints View payment history View request status (new, pending, and complete) Pay for service Receive notification (payment short message alert) Visualize news (solid waste information) Live chat through the official municipal WhatsApp number

Table 7: System non-functionalities

Non-functional requirement	Description
Business requirement	Approval of workflows and authorization levels of the system
Administrative function	The ability of the system to perform basic tasks like reporting.
Operation function	The ability of the system to operate on the handset which includes the operating system and hardware parameters.
Performance function	The ability of the system to perform the quantity of valuable tasks in a specific time.
Security function	The ability of the system to secure the data and privacy of the users
Maintenance function	The ability of the system to be useful and easy to support and technical assistance, which does not hinder the availability of other services.
User-friendly function	The ability of the system to be easy to learn, use, and understandable

4.1.6 Architectural System

Based on the needs of users, we designed the architectural mobile-based system (Fig. 14) and the data flow diagram (Fig. 15) in which internet users must connect the interfaces of the developed mobile application to the remote database. The mobile application allows the input of user

information then can transferred through the application interface to the server for storage. The mobile application receives, processes, and transmits information to the server and can retrieve the information from the server to the interface of the mobile application.

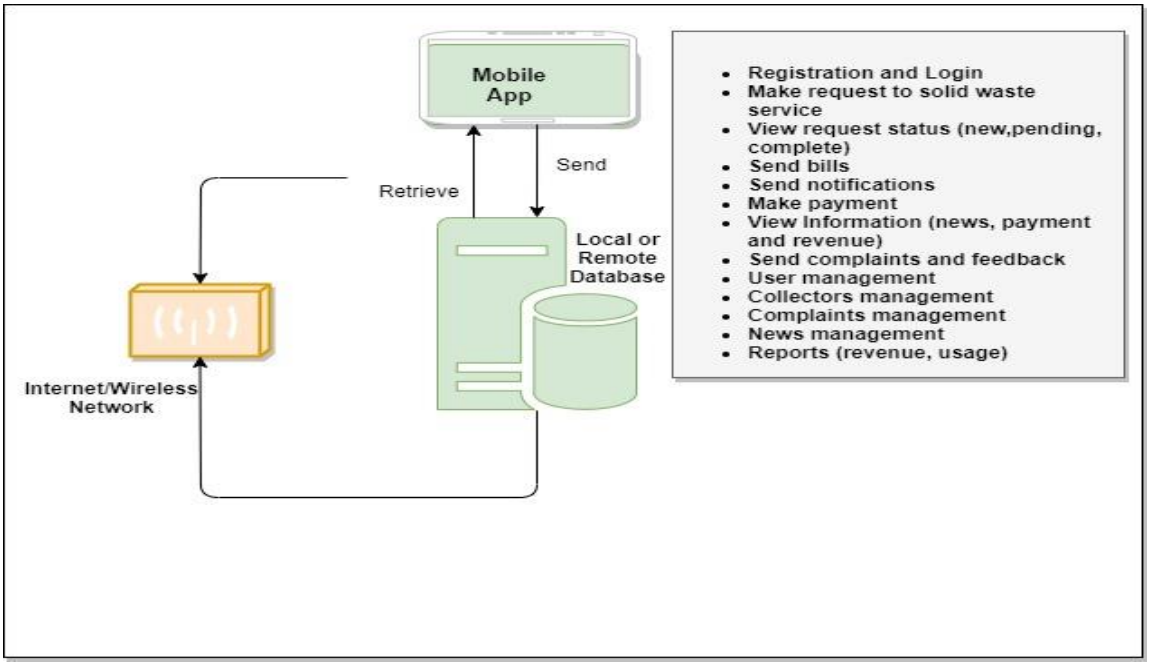


Figure 14: Architecture diagram of the mobile-based system

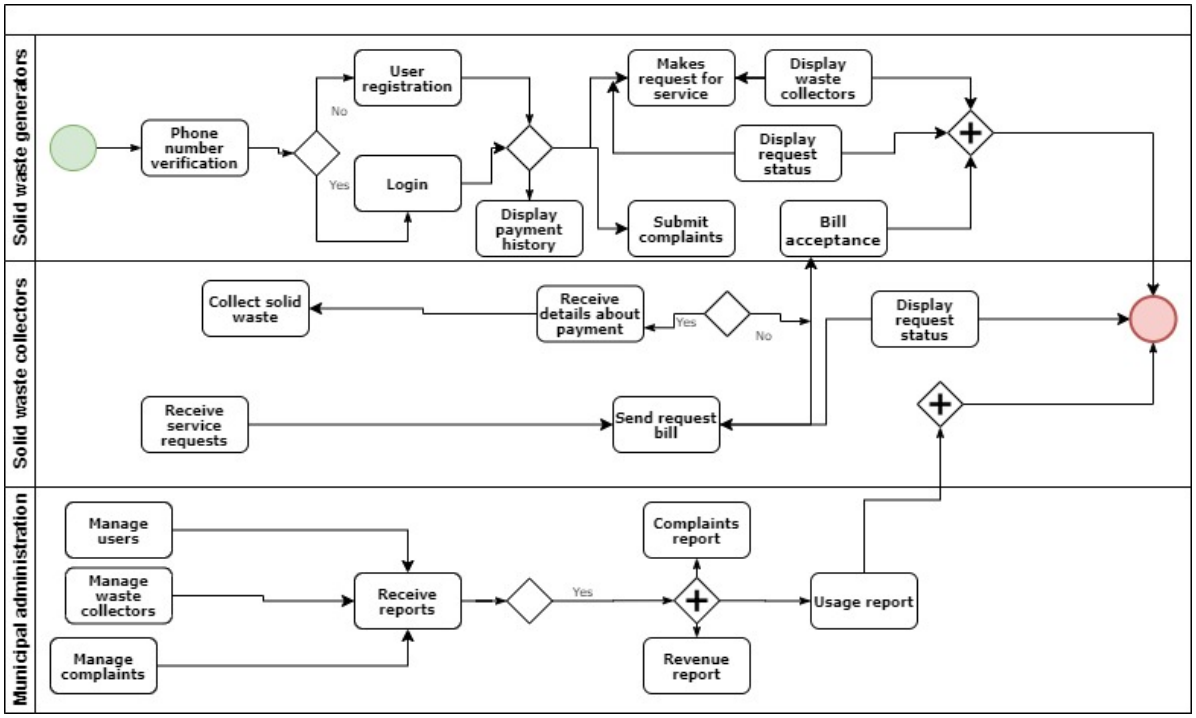


Figure 15: Data flow diagram for solid waste collection

4.1.7 Use Case Diagrams

In this study, the following use case diagram (Fig. 16) illustrates the way users (human or external systems) can interact with a mobile solid waste management application. It explains the business

at a theoretic level in which we captured the system we want to develop (Gomaa, 2011). The system has four actors who interact with the mobile application: (a) municipal officials given permission greater than others, (b) waste collectors who can log into the system after being verified approved by municipal officials, (c) users (households, institutions, shops, restaurants, and hotels) who can access the mobile application after verifying and registering their information, and (d) payment system that can interact with the mobile application for tracking all payment transactions as the confirmation of payment. Subsequently, these actors were classified according to the expected functions they would require from the mobile application (Table 8).

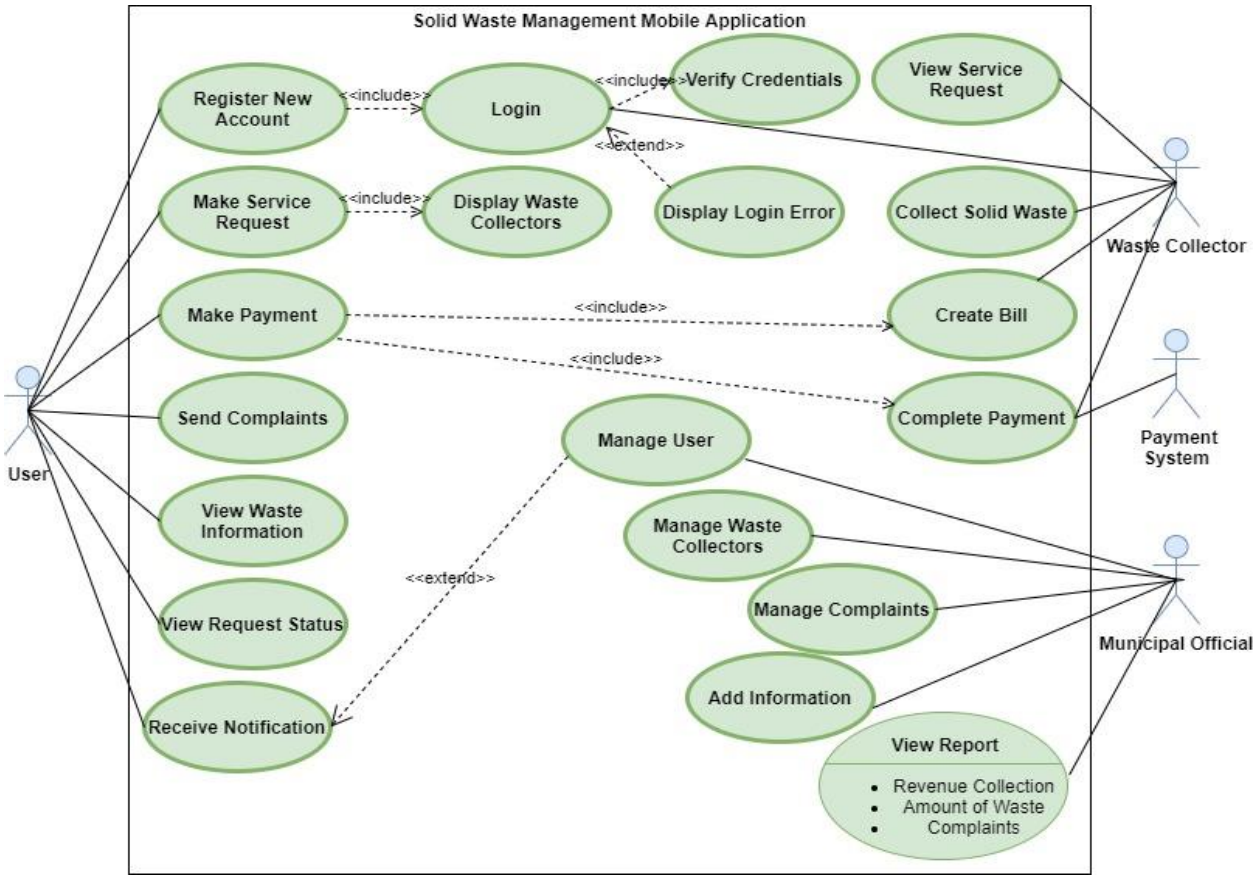


Figure 16: Use case diagram of the mobile-based system

4.1.8 Development of Mobile-Based System

The developed mobile-based system (*Zoataka*) consists of a phone verification interface (Fig. 17) in which a user must enter their phone number for verification before logging in and a registration interface (Fig. 18) for new system users whose information is not available in the developed system, such as personal names and location names. The user is authenticated for a single login session using this one-time dynamic and automatic verification code. These six numeric codes are safer than static passwords, particularly user-generated ones, which may be insecure or used for several accounts. The names of the location from the regional to the level of street are registered with the system developer where the app user selects the registered location of the area where the app user

lives. Additionally, users must get a verification code before logging in or registering with the system. This code will allow them to log in or submit the registration form (Fig. 19). Users visualized news and a list of solid waste collectors (Fig. 20), the status of their requests (Fig. 21), submitted complaints (Fig. 23), and submitted feedback (Fig. 24) according to their responsibilities (customers, solid waste collectors, and waste management service who are municipal officers). Furthermore, users were able to submit the request (Fig. 25) and visualize various reports such as complaints management (Fig. 26), user management (Fig. 27), user details with the option of sending a monthly payment short message system as an alert to users (Fig. 28), solid waste collectors' approval (Fig. 30) and solid waste news management (Fig. 31). The collection fee is different for different companies. For example, residents pay for the service pay T1000, organic shop pays TZS 2000, non-organic shop pays TZS 3000, small hotel pays TZS 5000 and large hotel pays TZS 10 per month as the cost of collecting waste. Therefore, the customer group determines the fee for waste collection service as shown in Fig. 22 of the payment history. These fees are set out in the SMC sanitation by-law.

Our app provides only payment history to customers who pay the solid waste collection service using mobile money. The collection business account in the Tigo mobile money, numbered 9353849 with the name CLOUDTHINKAGE, is a special account that has been deployed for receiving payments. Upon receiving a payment from the customer in this account, the system administrator is required to log into the mobile-based system to change the customer's payment status to indicate that the customer has paid so that the customer can continue to request the solid waste service. Therefore, our app can display the financial distribution statistics for transparency to waste collectors, council management at street, ward, and headquarters levels as shown in Fig. 29. By using the financial distribution data in our app, waste collectors will pay only a specific amount allocated to the street, ward and headquarters and use the amount allocated to them on time to cover the cost of solid waste collection including wages, rent of solid waste collection equipment and fuel without waiting for their commission from the council. The current system has the complaint that customers make cash payments for the service and waste collectors must pay all the revenue collected and submit it to the council bank account; then the council allocates the monthly commission to the waste collectors without allocating to the street and ward management. In addition to managing customer payment status and sending notifications to remind customers to pay for services, the mobile-based system administrator also has the ability to approve all waste collector applications (Fig. 30) and publish the various information related to solid waste management using our app (Fig. 31).

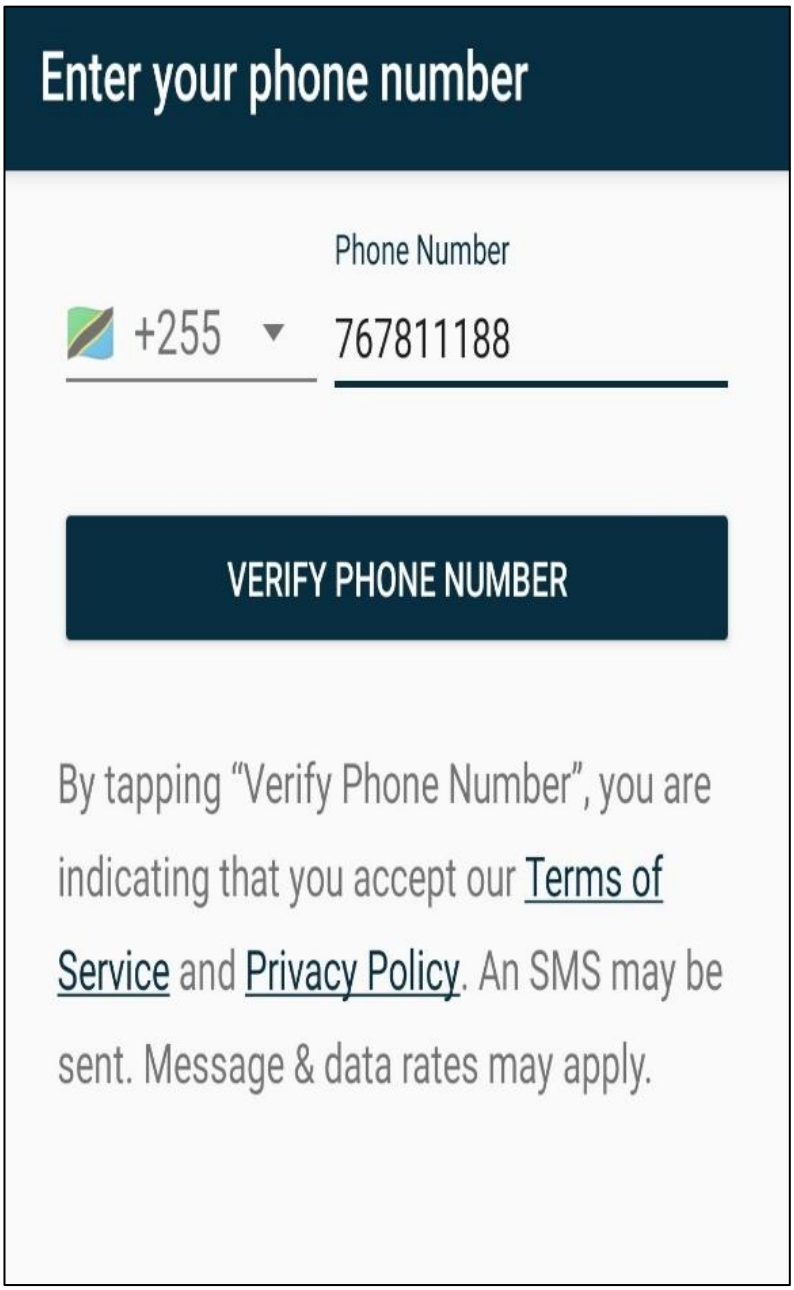


Figure 17: Phone verification interface

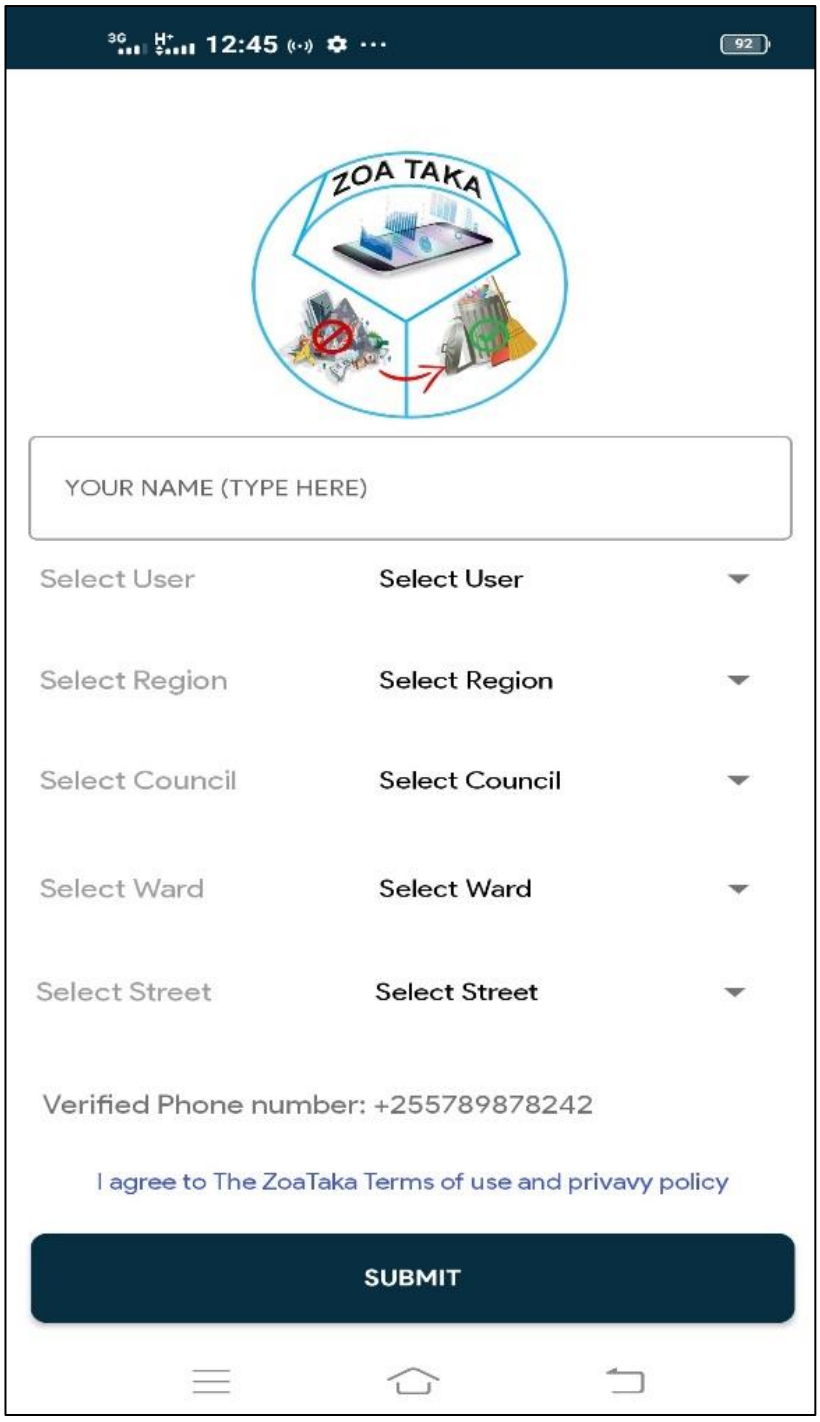


Figure 18: User registration interface

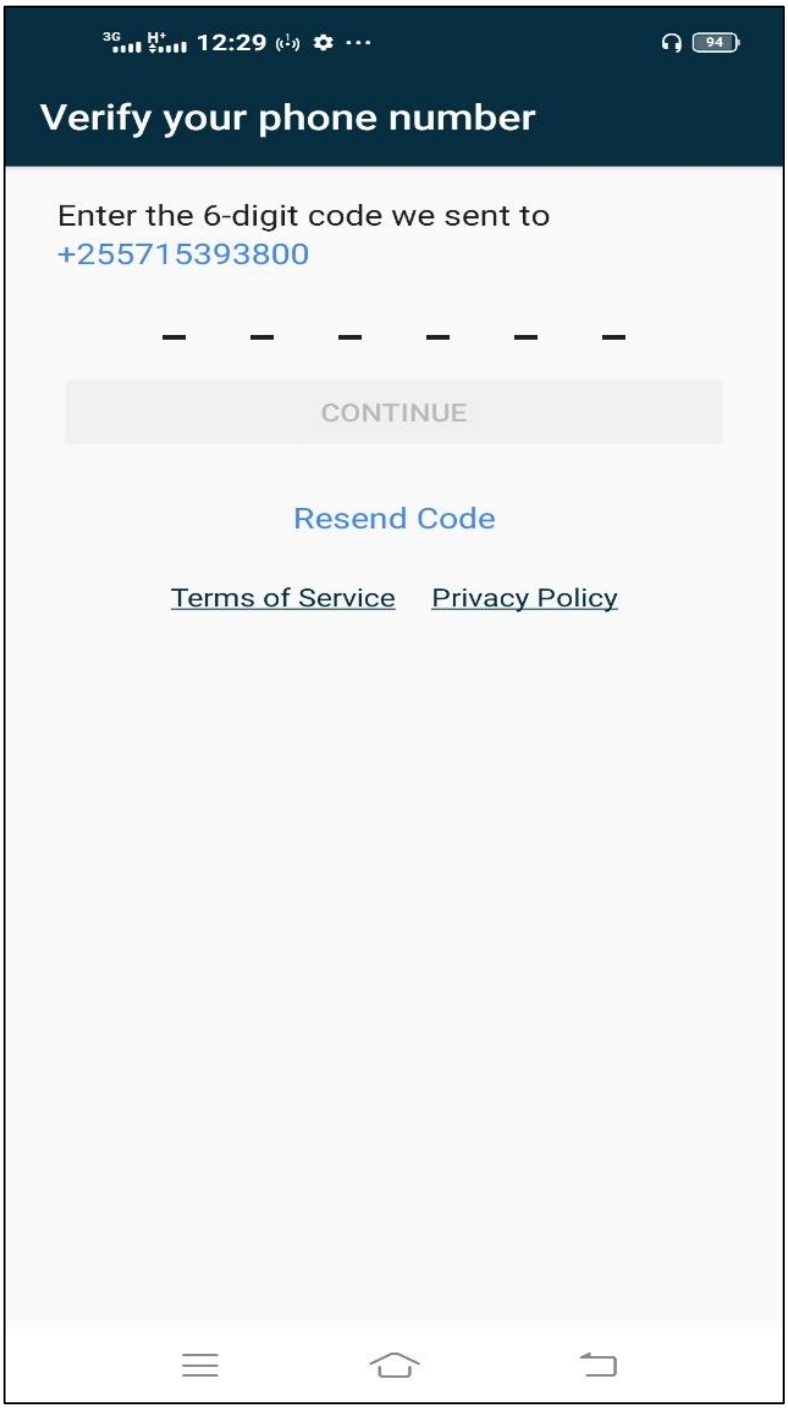


Figure 19: Interface of the verification code

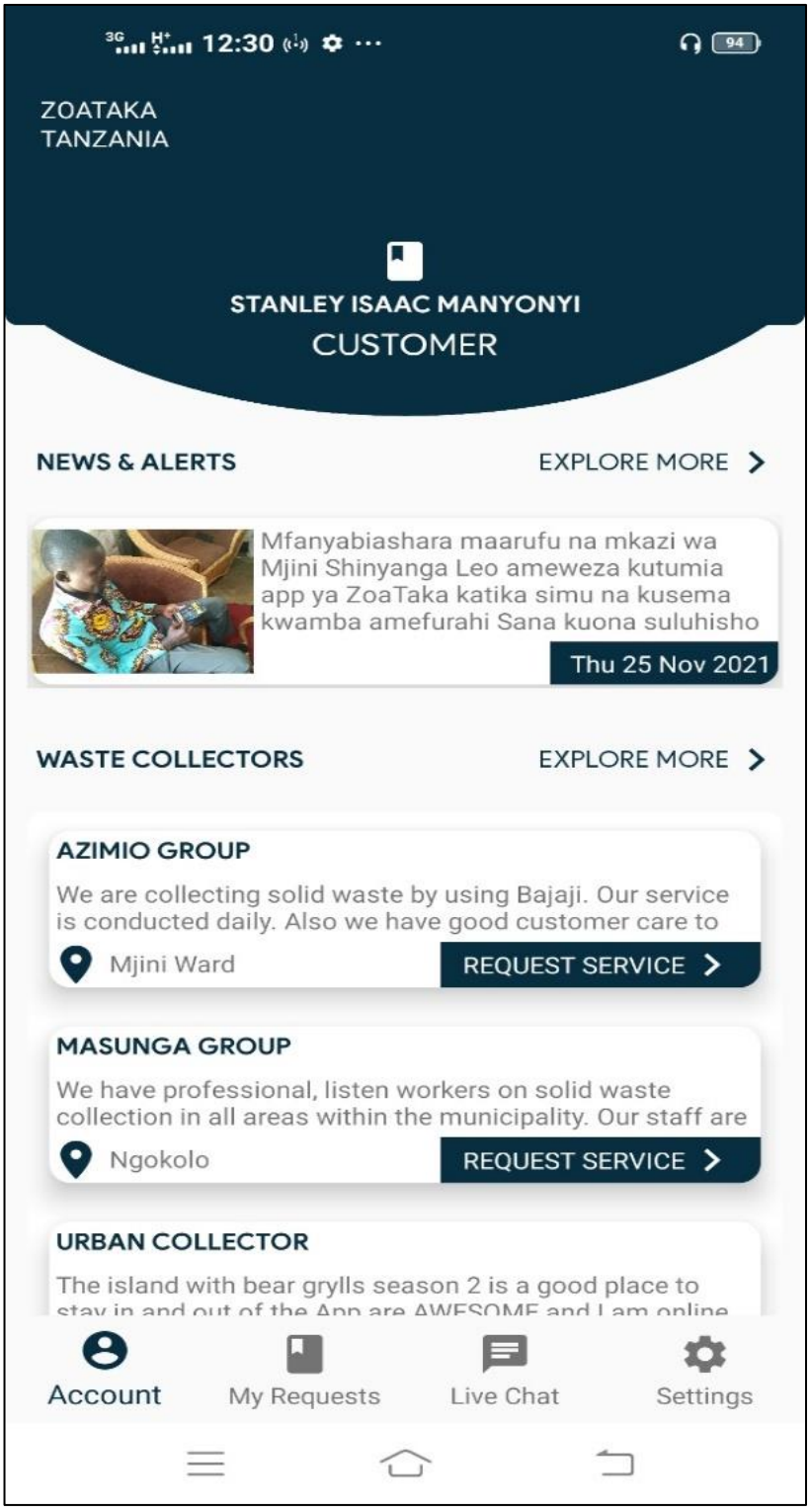


Figure 20: News and list of waste collectors

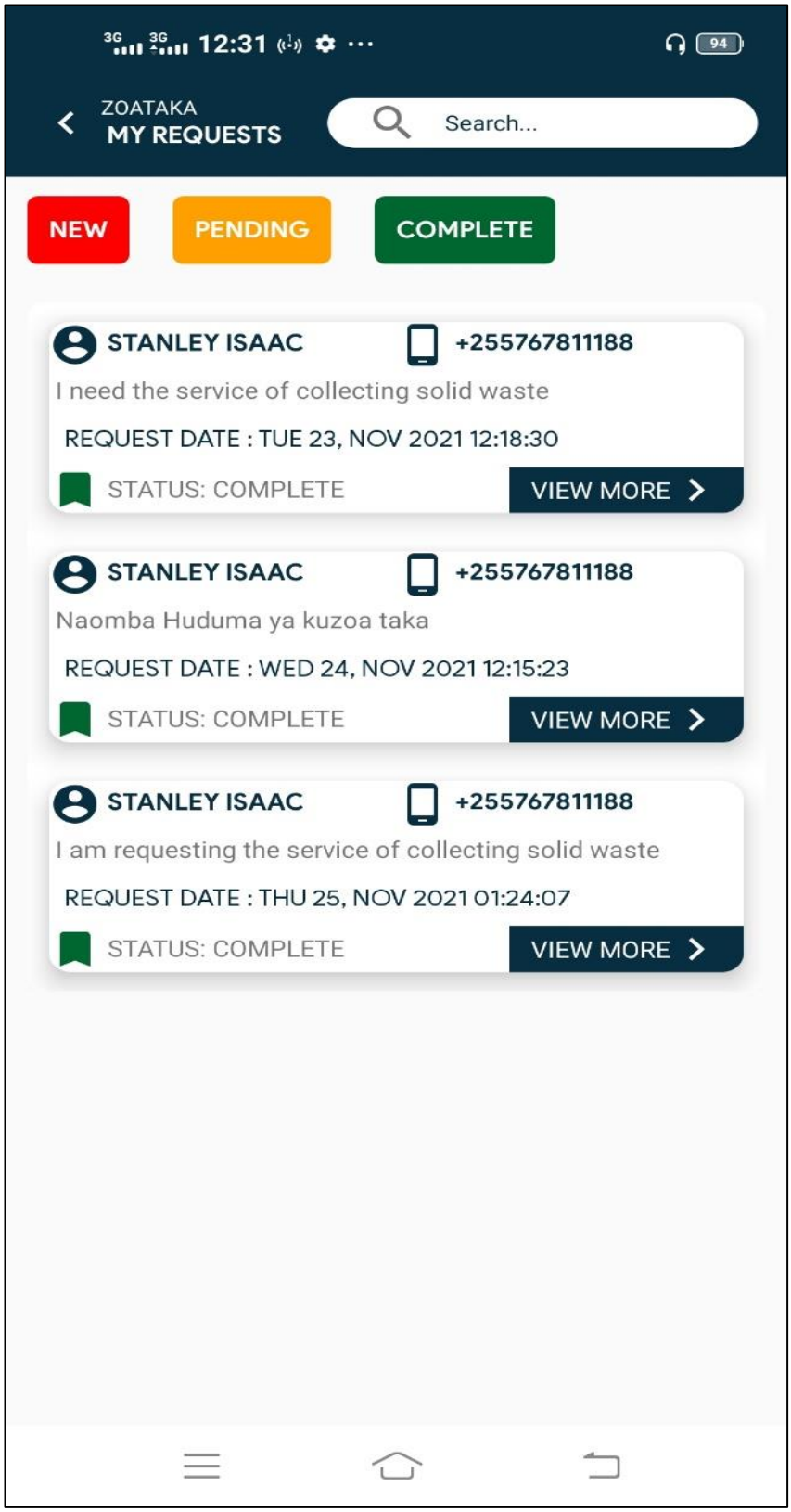


Figure 21: Request status interface

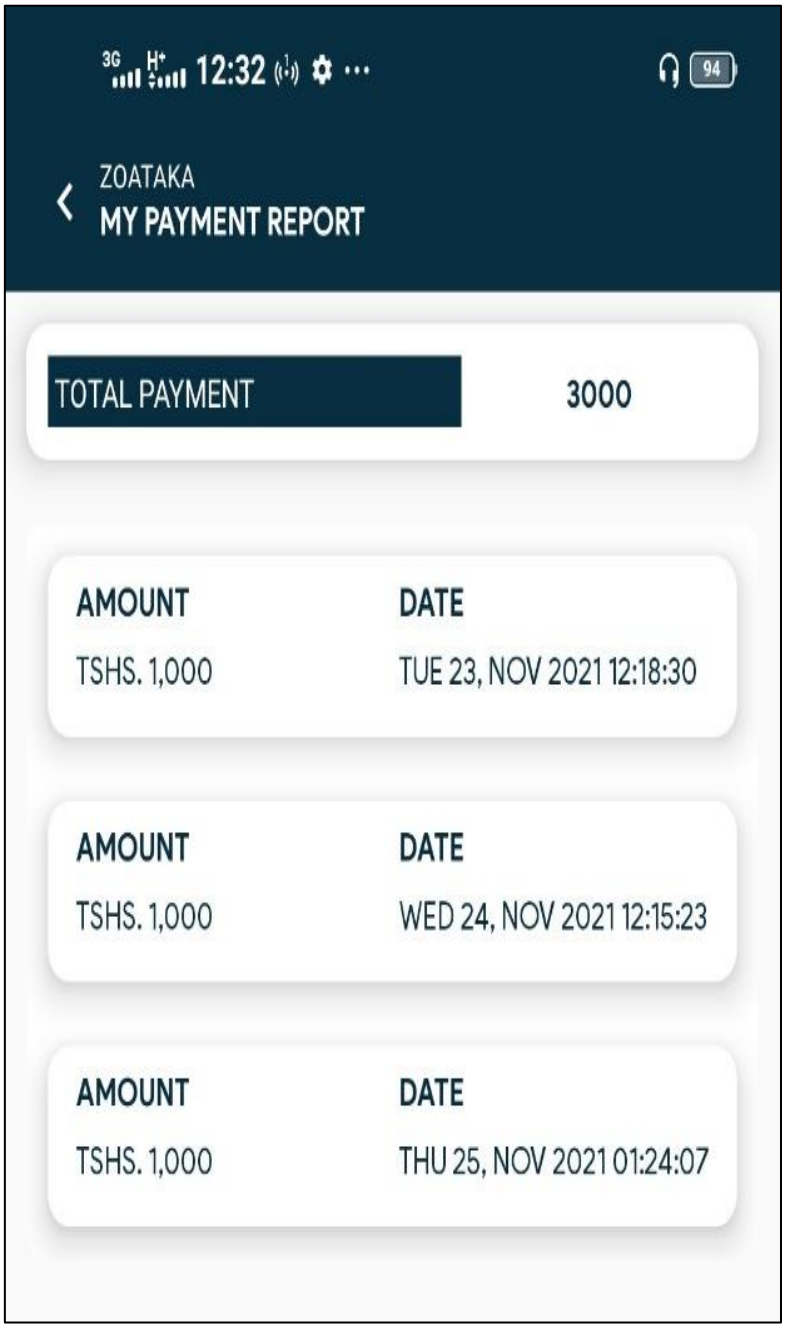


Figure 22: Payment history interface

Figure 23: Submit complaints interface

Figure 24: Submit feedback interface

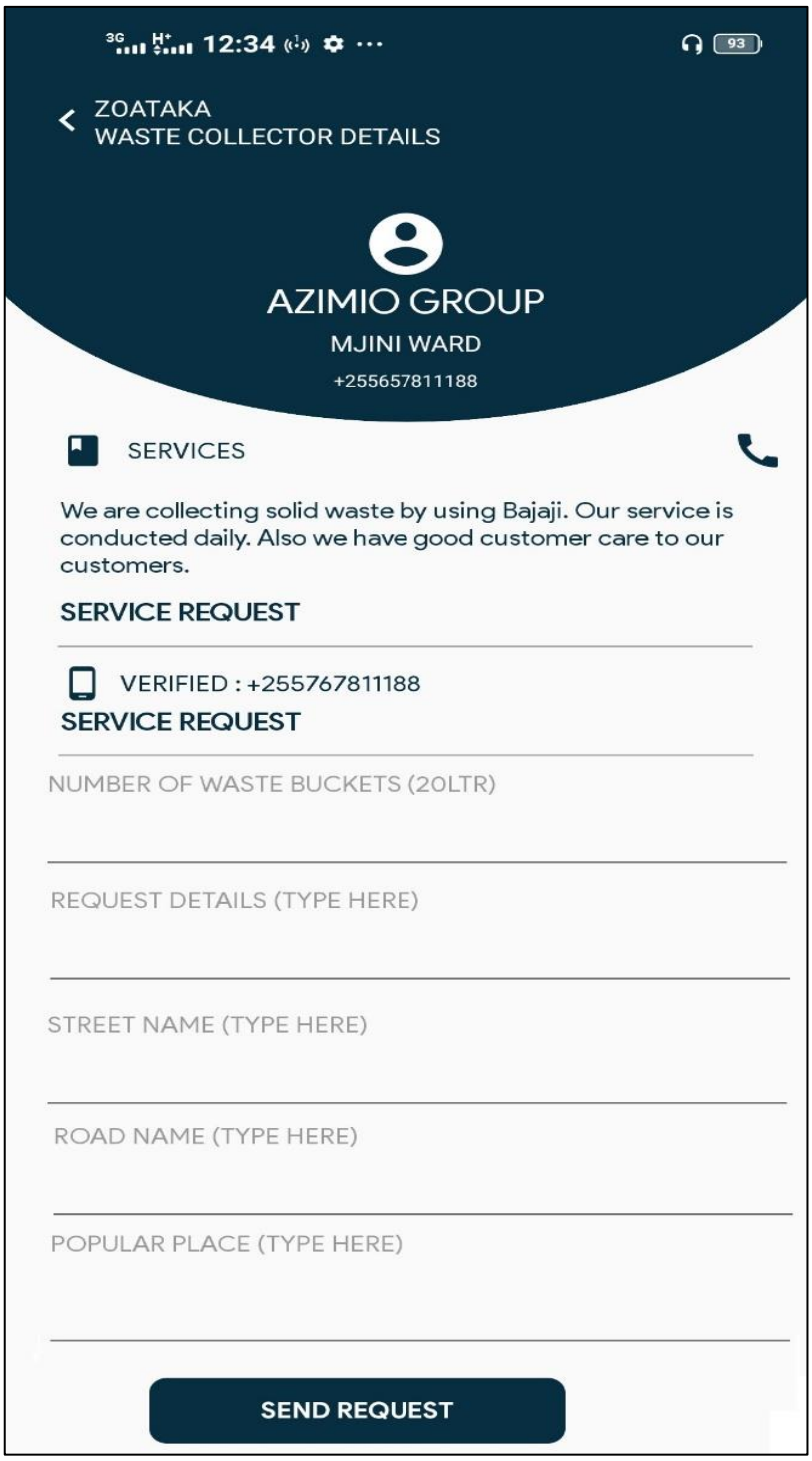


Figure 25: Send request interface

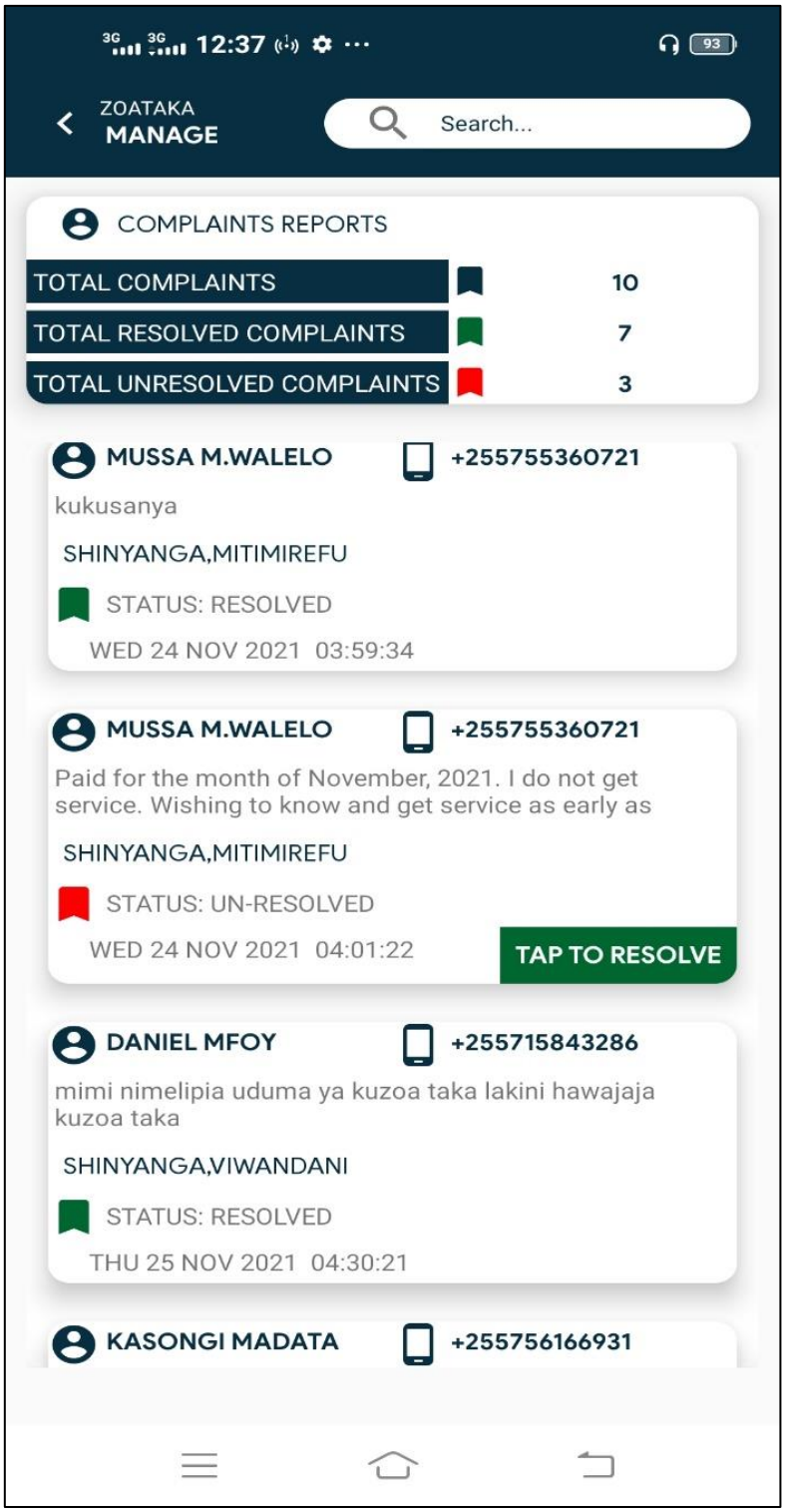


Figure 26: Manage complaints interface

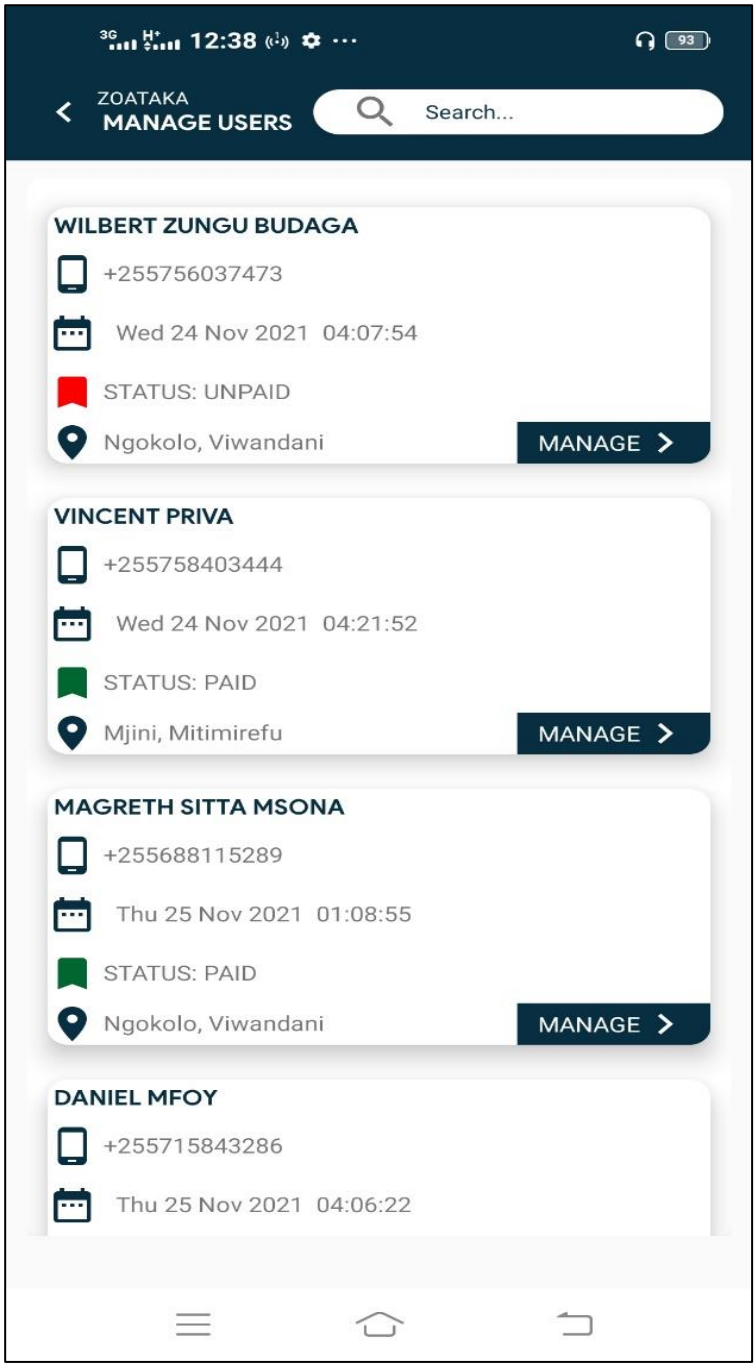


Figure 27: User management interface

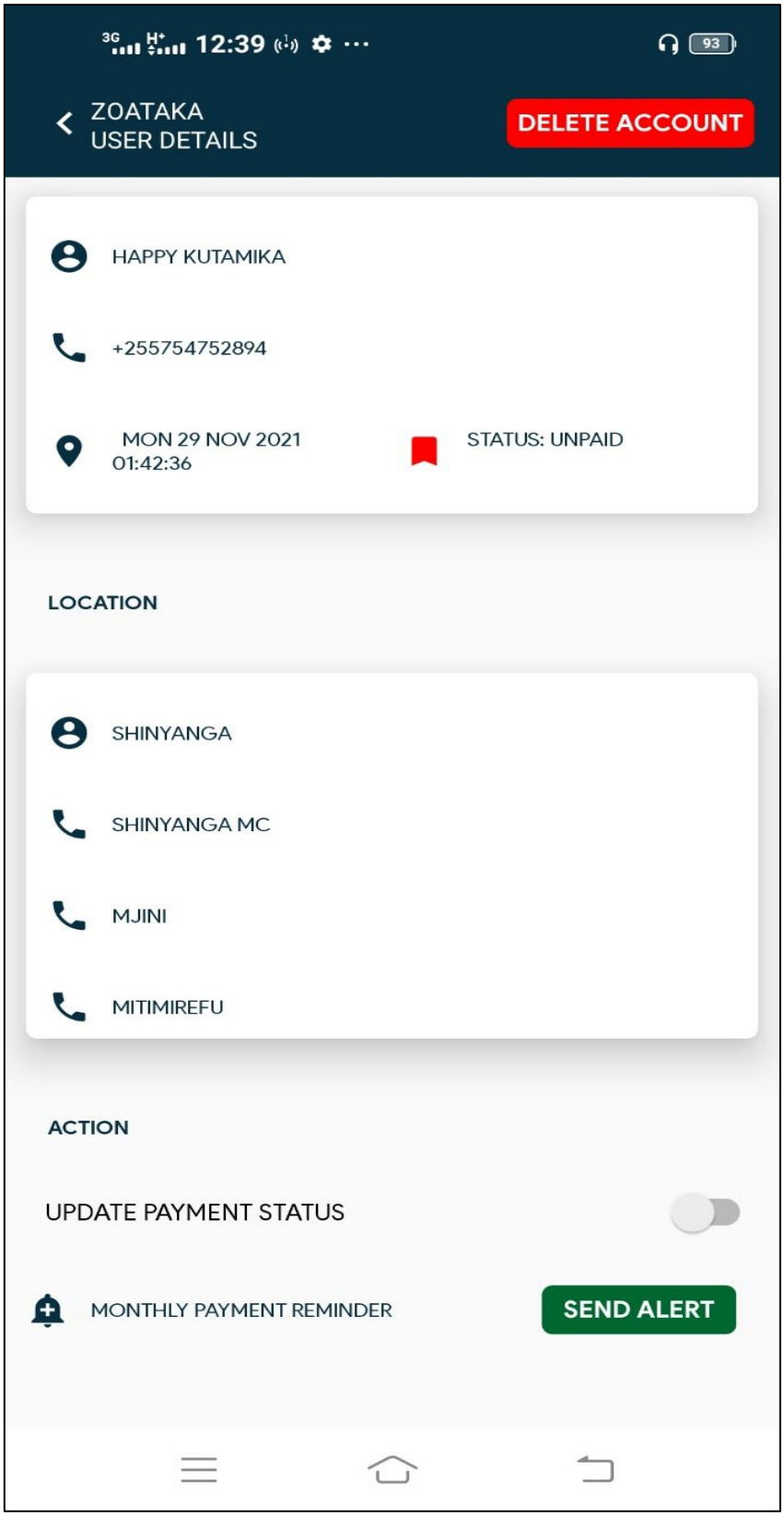


Figure 28: Send a payment reminder

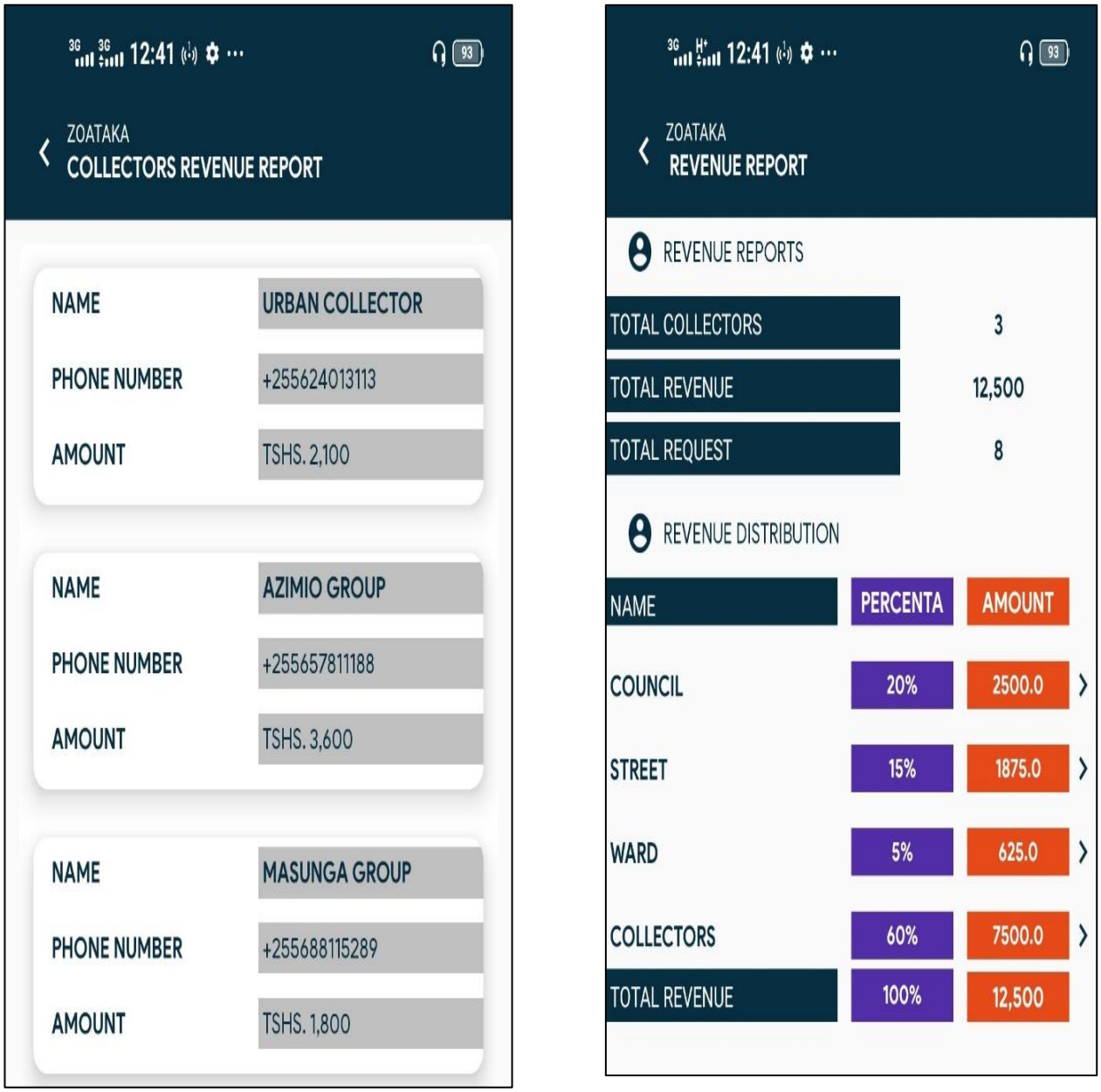


Figure 29: Revenue report and collectors distribution interfaces

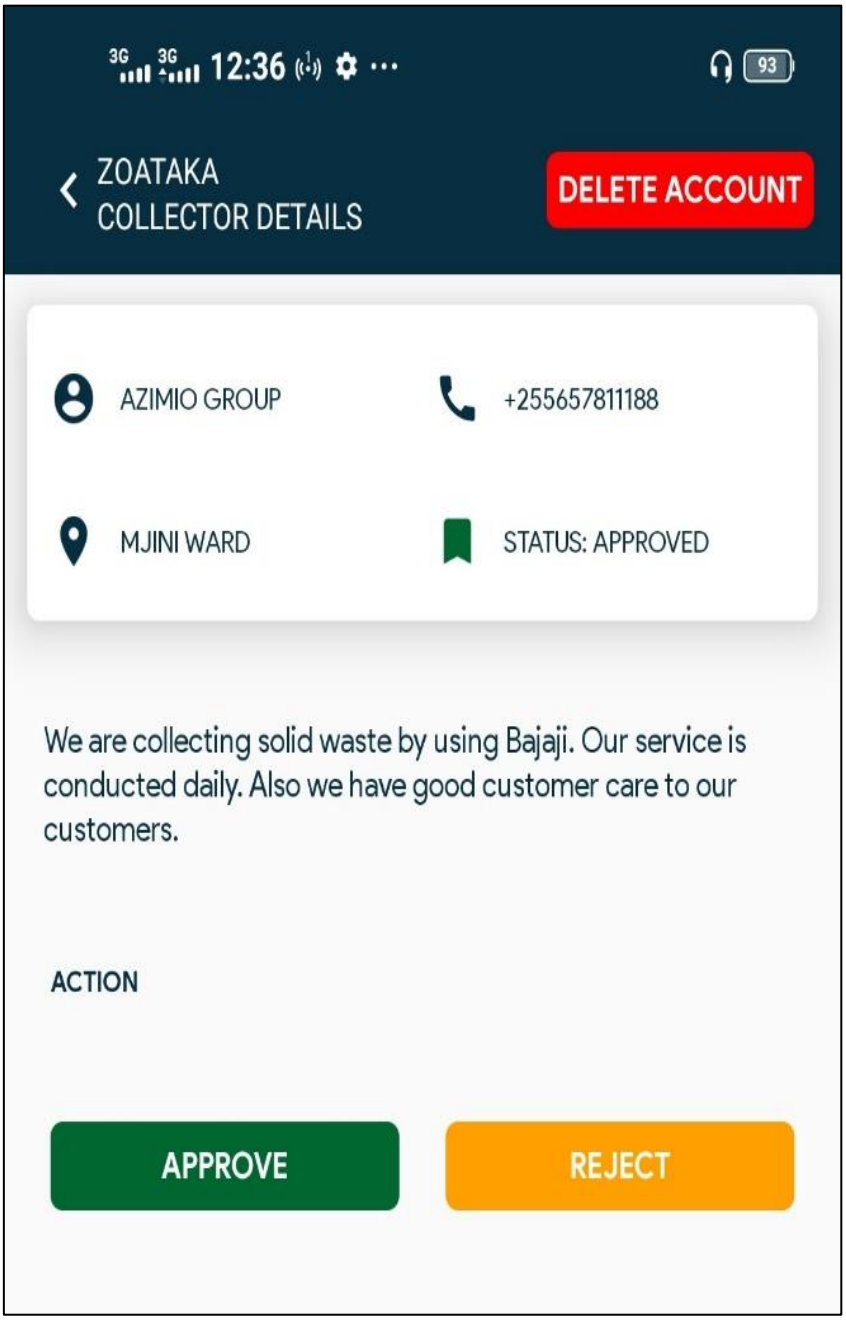


Figure 30: Approving waste collectors

Figure 31: News management interface

4.1.9 Evaluation of Mobile-Based System

Solid waste generators, waste collectors and municipal officers from Mitimirefu and Viwandani streets in the Mjini ward were used in the validation process to see if the mobile-based system is reliable and satisfies their essential business requirements. To evaluate their effectiveness and other performance characteristics, including availability, scalability, user friendliness, consistency, navigation, feedback, performance, and security were permitted to install the mobile system on their Android phones. The mobile-based system was readily accepted by respondents, who recommended that it should be implemented in real life settings because it would encourage several more local government authorities to adopt an electronic solid waste collection system that would discourage the use of cash payments for the service, increase revenue collection, improve customer satisfaction, and keep the environment clean. In similar way, the system was brought to the ICT unit in six local governments for testing: Shinyanga Municipal Council, Kahama Municipal Council, Shinyanga District Council, Msalala District Council, Ushetu District Council and Kishapu District Council. The system was approved by the ICT team with a few suggestions for improvements, such as using a government electronic gateway to obtain a payment control number and switching to English and Swahili language.

In addition, questionnaires were sent to 27 end users and 14 technical specialists to evaluate their information and experiences on the mobile-based system for solid waste management in Shinyanga municipality. Appendix 3 has the questionnaires check list. The developed mobile-based system for solid waste management was evaluated on a scale of Very High, High, Average, Low, or Very Low. Technical experts and end users were requested to rate each of the provided aspects. Technical experts evaluated the availability, scalability, user friendliness, consistency, navigation, feedback, performance, and security while end users evaluated the business requirements such as approval of workflows and authorization levels of the system; administrative functions such as the ability of the system to do basic tasks like reporting; user requirements such as the ability of the system to allow users to submit service requests or explore an online directory of solid waste collectors; system requirements such as the ability of the system to operate on the handset, which includes operating system and hardware parameters, system responses, clarity of the output, usefulness of the system, the requirement for support and technical assistance to use this mobile application, internet connectivity, possibility of using the system and recommending it to others. The results indicated that 64% of technical specialists gave the system a very high rating for the speed of the system to operate, while 57% gave the developed system a very high rating for the ability of the system to provide feedback (Fig. 32). On the other hand, 7% of technical specialists assigned an average rating to the security of the system. End-user evaluations revealed that 78% of the

evaluators were satisfied with the very high rating of usefulness and helpfulness of the developed mobile application and 70% rated the ability of the mobile system to function in their software and hardware specifications as very high (Fig. 33). Despite positive feedback from end users' evaluation, 3% were concerned about internet connectivity, willingness to use the application, and recommendation to others.

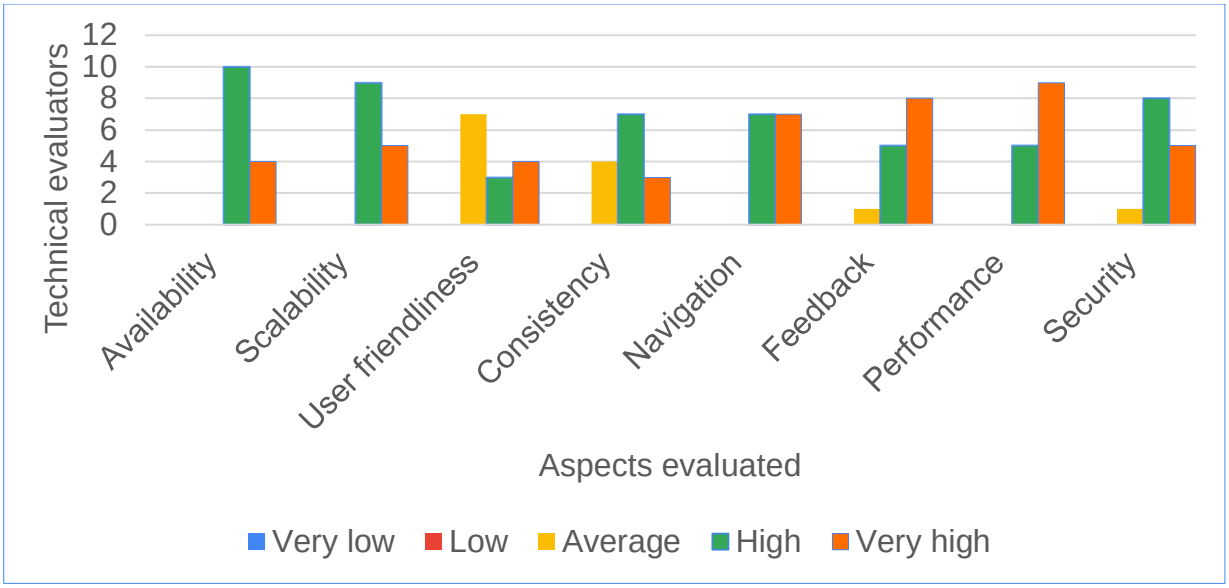


Figure 32: Technical evaluation results

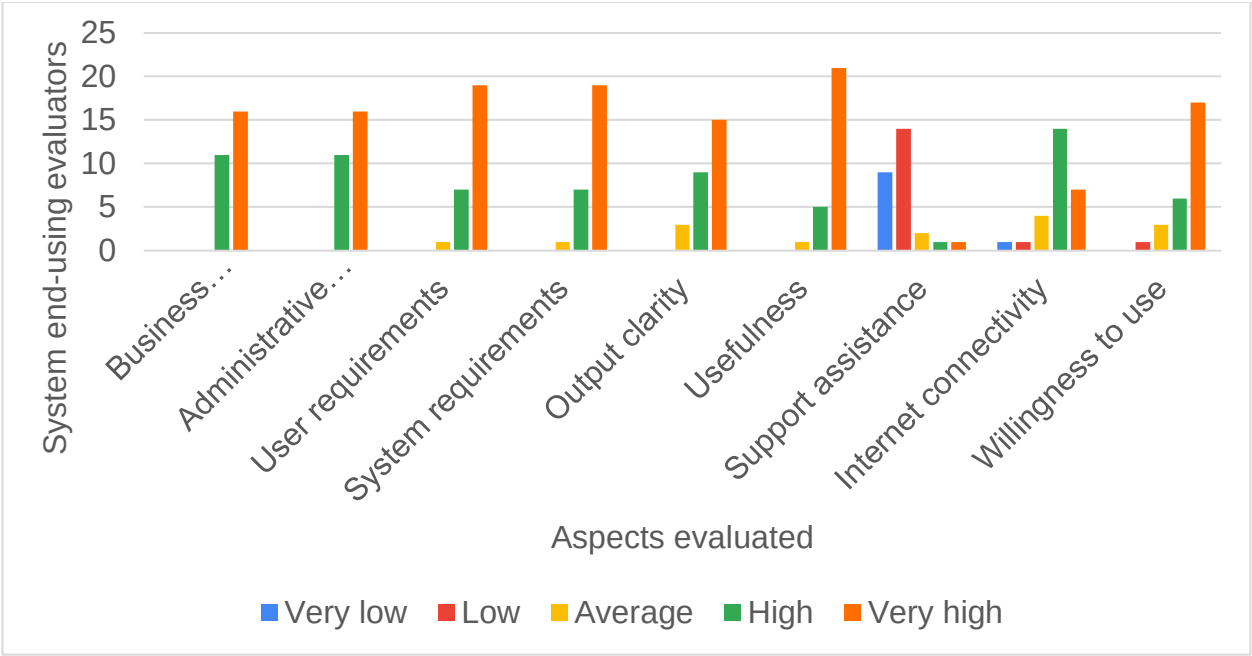


Figure 33: End-user evaluation result

Table 8: Mobile application testing for the key modules

Function of the mobile app	Description	Results
User verification	The user can enter the valid phone number and enable to register after receiving verification codes	PASS
	The mobile app displays error notifications when certain details are incorrectly entered.	PASS
	After completing the registration process, the user can access the mobile application	PASS
User login	When the credentials (phone number and password) are incorrect, the application prevents you from logging in	PASS
News and notification alerts	The app displays the most recent news and alerts.	PASS
	The user may access and read the most recent news and alerts	PASS
	The user can add news and images	PASS
	The user can delete old informatio.	PASS
Send a request for service	The user can send the request for solid waste collection service	PASS
	The app can display the list of waste collectors.	PASS
	The user can access the request status.	PASS
	The user can accept or reject the bill.	PASS
Send complaints	The user can send the complaints to the management	PASS
	The app can display the complaints status.	PASS
Payment	The user can view the payment history.	PASS
	The app can display the allocation of funds from revenue collections	PASS
User logout	The user can logout	PASS
Admin access	The app can list of waste collectors	
	The app can display the status of applying solid waste collectors	PASS
	The user can approve the application of waste collectors	PASS
	The user can reject the application of waste collectors	PASS
	The user can delete the account of the waste collector	PASS

4.2 Discussion

The main objective of this study was to develop a mobile-based system for solid waste management with the specific objectives of improving customer satisfaction and revenue collection. This mobile-based system monitors regular solid waste collection, a critical component of solid waste management, while tracking revenue collection from citizens who apply for the service of removing solid waste in their premises. In the last ten years, SMC has implemented house-to-house solid

waste collection. Furthermore, the 96 participants in this study mentioned the challenges of the solid waste collection system in SMC that make them dissatisfied or less satisfied with solid waste collection. To name the few reasons for dissatisfaction is that the frequency of solid waste collection is too low, is irregular, and not properly done. The dissatisfaction is due to the fact that the SMC authority has a great dependence on civilian groups contracted to provide solid waste collection services. Although this is a positive step in establishing a PPP, the SMC authorities (street, ward, and headquarter) and the solid waste collectors collectively complain of not seeing the benefits of revenue collection from solid waste revenue source because the costs of solid waste collection are higher than the revenue collected. Additionally, the cost of solid waste collection includes paying daily solid waste collectors wages, renting solid waste collection equipment such as wood-made wheelbarrows, purchasing fuel for solid waste transporting vehicles, and communications costs. Solid waste collectors have not deposited all collected revenue from citizens into the SMC bank account. The solid waste collectors explained that they immediately used the revenue they had collected to fund waste collection services because the SMC authority was delaying their commission of 60% of the collections. In addition, the council failed to fulfill its promise to provide waste collectors with solid waste collection equipment to reduce the cost of renting equipment. In fact, the SMC authority should implement a modern system which can organize and integrate all major solid waste stakeholders, including householders representing a group of solid waste producers, solid waste collectors and municipal officials. These three stakeholders in the solid waste collection system can focus on ensuring both an effective solid waste management process and much more decentralized system by offering them with a more systematic approach in which services and responsibilities are provided within multiple stakeholders to create an efficient distribution of information and resources.

According to participants in ten wards, solid waste collectors visited solid waste collection areas on an irregular schedule per month. The irregular schedule is due to the lack of communication and transparency between the solid waste producer, solid waste collectors, and the solid waste service management team. Political leaders at street (street chairperson) and ward (councilors) levels have stopped promoting and monitoring waste collection services simply because they do not receive a commission of 15 and 5%, respectively, of the revenue generated from solid waste collection in their areas. They claimed there is no transparency system and they do not know any collection information. They added that previously they had benefited from the revenue commission they were earning from solid waste revenues. Some of the mentioned benefits of such commission was the cost of running offices serving citizens and as incentives to either encourage citizens to pay for monthly waste collection services or tracking residents who refuse to pay for service. However, the

SMC authority prepared a solid waste collection schedule to facilitate access to information by disseminating such schedules in the offices of local government chairpersons and ward executive offices.

During the end user and technical evaluation of the developed system to identify and verify the meeting of the user and system specifications, it was revealed that the desired needs in business, administrative, user, and system requirements were considered and found in the developed mobile system. This means that the desire expected in the solid waste collection system was incorporated into the developed system, such as having professional solid waste collectors who arrive on time, a friendly and easy payment system, a current and relevant solid waste information platform, and reducing the overcrowd of solid waste in the dumping sites. More than 50% of the evaluates were satisfied that, to name a few, they have been able to submit requests for solid waste collection service, submit their complaints, pay for services without giving cash to waste collectors, view payment history, view revenue distribution and view submitted complaints. This systematic approach of integrating solid waste collectors, solid waste generators, and SMC authority, with the adoption and willingness of using the mobile-based system (*Zoataka app*), can help improve the solid waste collection process, customer satisfaction, and revenue collection.

The SMC solid waste is collected from house to house using trolleys, carts pushed by solid waste collectors, three-wheeled motorcycles and tippers. There are no proper trucks for transporting compostable and reusable solid waste materials, and hook loaders for waste carried off carts and trucks. In the four trial wards (Mjini, Ngokolo, Ndembezi and Kambarage) the mode of transportation used to transfer solid waste to the main dumping site was tippers, while wood-made carts were observed to be more prevalent to the rest of wards. Furthermore, it was claimed that the waste transport facilities are limited to collect solid waste in all areas in an order that does not correlate with the current requirements for the generation of solid waste. This results in insect breeding grounds and an unpleasant smell arise from the rotting solid waste while it waits to be collected and transported, especially in areas where solid waste generation is high. This study has revealed that there is an unfriendly environment for accessing information on waste collection and transportation needs from citizens to waste collectors. To address the mentioned concern, a mobile-based system that enables a solid waste generator to report and request a waste collection service in their areas is urgently needed to enable solid waste collectors and municipal waste supervisors to organize on time the human and waste collection resources based on waste available. To minimize delays, solid waste collectors will use the system to set the collection time or other alternative preparations will be taken to avoid the congestion of waste collection activities and dissatisfaction.

According to the results, most of the respondents relied on direct personal contacts with waste collectors and government officials, either by visiting them or by telephone, to share information about waste management services. To minimize the challenge of finding waste collectors and municipal employees in their workplace, our system has considered this by setting up a feature to send complaints, comments, and live chat to facilitate communication and solving challenges in a timely manner electronically. Numerous previous studies have shown similar results, which these findings support by showing that mobile technologies enable citizens to collect and share data to promote community action, which ultimately results in beneficial societal transformation (Nagendra *et al.,* 2019). Communities can transform due to the availability of infrastructure that enables them to submit their views and receive timely feedback.

The following are advantages of utilizing the *Zoataka* app for different user subgroups:

(i) The SMC Municipal residents: A mobile based system will enable them to submit request for a waste collection service once their solid waste cans are full, communicate their emotions about the service, receive various information related to solid waste management to increase their knowledge of environmental protection and to simplify the payment process for solid waste collection services.

(ii) Waste collectors: Their work of collecting solid waste will be simplified because the mobile based system will enable them to view and manage the status of requests from the residents on time and anywhere. It will also help them plan alternative preparations early to minimize delays and running costs in waste collection.

(iii) Municipal officers: By using the mobile application, their activity on waste management process such as management of solid waste collectors, complaints, users, revenue, and usage will go more smoothly because the management reports will be well arranged using the mobile application.

(iv) Political leaders (Municipal councilors and local government chairpersons): By requesting the revenue distribution reports from the municipal officials responsible for waste management, the mobile system will assist political leaders to cooperate with both the parties they lead (citizens and municipal authority) in managing the solid waste collection service because the system will display transparent information on revenue collection, revenue distributions, and the status of complaints. It will promote accountability for all parties, from the street level to the municipal authority.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Using the findings of the Shinyanga Municipal Council, this study aimed to develop a mobile-based system for solid waste management with the specific objectives of improving customer satisfaction and revenue collection. In the first specific objective, an effective data analysis of the current solid waste system in SMC was provided.

The second specific objective was to design and develop a mobile application for the management of solid waste. The objective was to demonstrate the ability of a mobile-based system to connect communication between major waste stakeholders, such as solid waste generators, solid waste collectors, and sanitation activities supervisors in the SMC authority, using their desired requirements. Additionally, the data collection procedure was presented. Finally, it resulted in the development of the proposed mobile system, which can effectively influence the satisfaction of residents with solid waste collection services and enhance revenue collection.

The third specific goal was to validate a mobile-based system for solid management in the targeted municipality. The validation process made use of data from the Mitimirefu and Viwandani streets in Mjini ward. The developed mobile system achieved an average rate of 64% from the technical specialists who gave the system a very high rating for its speed of operation, while 57% gave the developed system a very high rating for its ability to provide feedback. The evaluation of the study revealed that 85% of end users agreed that the developed mobile system will add value due to its usefulness in the management of solid waste in their areas.

The ever-increasing use of mobile telephones, particularly the internet and mobile applications, has been found to be useful for the delivery of solid waste information in this study. Most of the participants in this study agreed that a smartphone application system for the delivery of solid waste information is necessary. The municipal health and sanitation professionals of the SMC agreed with this necessity. Both solid waste generators, solid waste collectors, and SMC health and sanitation practitioners indicated that a mobile application system was needed to share solid waste information among them and that they would utilize it and recommend it to others.

According to the findings of the study, the use of mobile-based systems is critical in sharing solid waste information. Mobile application systems will enable users to voluntarily access solid waste information on their mobile devices regularly without having to physically visit the office. As an

outcome, there will be more timely and high-quality access to solid waste information and a transformation in attitude to minimize complaints, criticisms, and protests and promote a culture of positive thinking about solutions to the risks caused by solid waste pollution. For a significant increase and impact, the accessibility of solid waste information must align with the Internet and mobile phones. This is significant in this information sharing era, when the majority of people possess mobile phones with Internet usability.

5.2 Recommendations

The developed mobile-based system (Zoataka) has successfully achieved business needs and administrative functions such as service request submission, complaint management, news and revenue report visualization. We advise SMC residents, waste collectors, public and private institutions, the President's Office, Regional Administration and Local Government of Tanzania, NGOs and other environmental stakeholders to use Zoataka to provide solid waste management services and address communication challenges to improve customer satisfaction and revenue collection.

For management and decision making, the developed mobile system only considers recording of requests for solid waste services and revenue collections. Other studies could be conducted to employ Zoataka as a data gathering tool and integrate the resulting information into the app's tracking and estimating solid waste generation rates and payment rates for solid waste collection services to increase resident satisfaction and revenue collection.

Data from one ward were used to validate the developed mobile app during the development of this mobile app. Other studies should improve on *Zoataka* by integrating more data from numerous wards and other local government authorities in Tanzania, and cost-benefit analysis and socioeconomic elements not included in our developed mobile app related to time and expense constraints.

Households, solid waste collectors from ten wards with large, medium and small solid waste generation rates, and SMC health and sanitation officers were all involved in the study. Due to the generation of solid waste, we strongly advise that PO-RALG, MoEST, NGOs, and other researchers conduct surveys for all other local government authorities in Tanzania to collect more detailed information that will contribute to the development of mobile systems to address the problem of solid waste generation in Tanzania.

Our research found that the smartphone purchase rate is high, that most residents have used a

smartphone before and know how to use it, that few people need help using it, and the presence of good cellular networks are among the main benefits that encourage the development of a mobile system for solid waste management in Shinyanga, Tanzania. Other problems, such as the need for assistance, were viewed by the participants in our study as balanced by the benefits that a mobile app solution can provide. This served as the foundation for the development of a mobile solid waste management application. The findings of this study are expected to contribute to the advancement of waste management technologies such as IoT and machine learning, particularly for residents disadvantaged in the sharing of information about solid waste disposal.

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APPENDICES

Appendix 1: Research Questionnaires

Developing Mobile Application for Solid Waste Management: A Case of Shinyanga Municipal Council.

Dear respondent,

My name is STANLEY ISAAC MANYONYI, I am conducting research on developing a mobile application for solid waste management as a project report submission in partial fulfillment of the requirements for the MSc. IN EMBEDDED AND MOBILE SYSTEMS of the NELSON MANDELA AFRICAN INSTITUTION OF SCIENCE AND TECHNOLOGY, Arusha, Tanzania.

This questionnaire is designed to facilitate the evaluation of the current situation of the solid waste management service in Shinyanga Municipality. The information collected by this questionnaire for all areas of the Shinyanga Municipal Council, in turn, can be used to develop a mobile application and evaluate the status of the solid waste management sector in towns and cities.

To accomplish this, I humbly ask you to spend a few minutes filling out this questionnaire. Since this survey is supposed to be free and fair, I encourage you to express your experience with our municipal/community solid waste management system. Although participation in this survey is optional, I kindly request that you participate fully to identify areas that need improvement to improve the performance of solid waste management and provide better services through the mobile application developed. Additionally, the results of the study are expected to improve the understanding of policymakers about current challenges and serve as an important tool for possible recovery strategies and interventions.

Remember that the information you provide will be highly confidential and will be anonymous. If you have any questions about the survey, please email me: manyonyis@nm-aist.ac.tz or 0767811188, the supervisor email is silas.mirau@nm-aist.ac.tz (Dr Silas Mirau 0713911463) and mussa.ally@nm-aist.ac.tz (Dr Mussa Ally) and kkuchibanda@gmail.com (Mr Kuchibanda K Snatus 0784499982/0767499982)

I really appreciate your input!

1. Personal Information

a) What gender do you identify as? ☐ Male ☐ Female

b) Which category below includes your age?

☐ Below 20 years old ☐ 21-40 years old ☐ 41-60 years old ☐ Above 60 years old

c) Where is your household located?

☐ Mjini ☐ Kambarage ☐ Ngokolo ☐ Ndembezi ☐ Chamaguha

☐ Lubaga ☐ Ndala ☐ Masekelo ☐ Ibinzamata ☐ Kitangili

d) How long is your household being in the location where you live now?

☐ 0 to 4 years ☐ 5 to10 years ☐ Above 10 years

e) Is there a family member owning a smartphone in your household?

☐ Yes ☐ No

f) What kind of smartphone (kind of operating system) is owned?

☐ Android ☐ iPhone ☐ Both Android and iPhone ☐ Neither Android nor iPhone

g) What is the highest level of education you have completed?

☐ Primary education ☐ Secondary education ☐ College/University

☐ Not attended formal education

h) Which of the following categories best describes your employment status?

☐ Employed for wages ☐ Self-employed ☐ Retired

i) How many occupants are in your household?

☐ None ☐ 1 ☐ 2 to 4 ☐ More than 4

j) Which of the following categories best describes your income status per month?

☐ Tsh 0-50,000 ☐ Tsh 50,001-100,000 ☐ Tsh 100,001-150,000

☐ Tsh 150,001-200,000 ☐ More than Tsh 200,000

2. Awareness and attitude on waste management in Shinyanga Municipal Council

a) Is there waste collection service in your area?

☐ Yes ☐ No

b) How is your garbage collected? (Select all that apply)

☐ Carrying to collection truck ☐ Carrying to collection point

☐ Placing outside ☐ Other……

c) What is the composition of the solid waste generated at your household? (Select all that apply)

☐ Food waste ☐ Plastics and glasses ☐ Papers

☐ Electrical and electronics waste ☐ Other…….

d) How often the generated solid waste is collected by the waste collectors?

☐ Daily ☐ Weekly ☐ Monthly ☐ Irregular ☐ Don't know

e) Are you satisfied with the waste collection service in your area?

☐ Very satisfied ☐ Less Satisfied ☐ Not Satisfied

f) What are the reasons for dissatisfaction? (Select all that apply)

☐ Not properly done ☐ Frequency too low ☐ Is irregular

☐ Too early or too late ☐ Service not fair ☐ Bad workers behavior

☐ Other……...

g) Have you ever complained about the garbage collection service to the authority in the last 2 years? ☐ Yes ☐ No

h) What communication method did you use to send your complaint to the authorities? Select all that apply ☐ Phone call ☐ Email ☐ Face to face ☐ No complaints

i) What do you believe about the responsibility towards environment sanitation?

☐ Public ☐ Government ☐ Both public and government ☐ Don't know

j) What incentives are provided to citizens/public who engage well in solid waste management? select all that apply Rewards ☐ No incentives ☐

☐ Free waste disposal equipment ☐ Other…….

k) How do you dispose generated solid waste in your premises? select all that apply

☐ Open dump ☐ Plastic buckets ☐ Plastic bags ☐ Boxes

☐ Burring ☐ Illegal dumping ☐ Give for recycling ☐ Other…….

l) How often do you dispose generated solid waste in your premises?

☐ As soon as possible ☐ Once daily ☐ less frequency ☐ Other…….

m) Is there someone who comes around your premises to collect your reusable or recyclable materials? ☐ Yes ☐ No ☐ Don't know

n) Do you separate any of your waste when you are disposing? ☐ Yes ☐ No

o) If NO in 2 (n) above, what are the reasons for not separating solid waste in your premises? select all that apply ☐ Expensive to have more than 1 container ☐ Not interested ☐ Not known to me ☐ No space for containers ☐ Other…….

p) What is lifestyle related activities that generate waste at your premises? select all that apply

☐ Daily cleaning routine inside and outside. Cooking and eating habit

☐ Food related informal business activities such as selling food, vegetables, fruits

☐ Other.....

3. Obstacles seen in getting to desired future services

a) What tasks are you trying to perform and complete when you seek the service of waste collection at your household? select all that apply

☐ Call waste collector ☐ Find transportation ☐ Make payment

☐ Segregate solid waste ☐ Search waste information ☐ Find market place for solid waste ☐ Give waste location ☐ Other……

b) What negative emotions, undesired costs and situations, risks that you experience in waste collection? select all that apply

☐ Wait a waste collector for a long time ☐ Charged without getting service

☐ Paying informal waste collector (Increase waste collection cost)

☐ Visited by informal street waste collector (unsafe waste collectors)

☐ Mixing waste (No segregation) ☐ Lack or wrong information

☐ No/low income from waste market ☐ Get rotten smell ☐ Other……

4. Desired future of waste management in Shinyanga Municipality

a) What benefits you desire or you expect to experience in waste collection? select all that apply

☐ Waste collectors to arrive on time ☐ Fair service and uniform price

☐ Professional waste collectors ☐ Friendly and Easy payment

☐ Current and relevant information ☐ Generate income from waste

☐ Reduce overcrowd of waste in the dumpsite ☐ Other……...

b) How can households encourage residents to be active in the proper management of waste? select all that apply ☐ Increase resources (Human and Fund) ☐ Increase publicity and awareness

☐ Other……

c) Are you willing to pay the waste collection fee in your area? ☐ Yes ☐ No

d) Are there any other suggestion that you may have, could help improve public participation in solid waste management in Shinyanga Municipality?.....

Appendix 2: Interview Guiding Questions

Q1. Solid Waste Collection to Waste management efficiency

Tell me about what the group does to manage solid waste in the community environment?

a) How solid waste are collected?

b) Do householders separate their own waste by type?

Q2. Barriers

In your opinion, how effective has the solid waste collection been in your municipality?

a) Why do you think it has been/not effective?

b) What would you do to solve the current problem? (if there is one)

Q3. Reporting system

With your familiarity with using the current solid waste framework for a while, what is it about solid waste reports that you make and keep it in your experience?

Appendix 3: Technical and end-user Evaluation Questions

a)

ZoaTaka App End-user Evaluation Questionnaire

My name is STANLEY ISAAC MANYONYI, I am conducting research on Developing Mobile Application for Solid Waste Management as a Project Report Submission in Partial Fulfillment of the Requirements for the Degree of MSc. IN EMBEDDED AND MOBILE SYSTEMS of the NELSON MANDELA AFRICAN INSTITUTION OF SCIENCE AND TECHNOLOGY, Arusha, Tanzania.

This questionnaire is designed to facilitate the assessment of the developed mobile application solid waste management service in Shinyanga Municipality (ZoaTaka App). End users are requested to rate each of the presented aspects into a scale of either Very High, High, Average, Low or Very Low. The aspects to be evaluated by end users are business requirements such as online payment system, online complains system etc; Administrative functions such as reporting system; User requirements such as such as place an solid waste collection order or browse the online list of waste collectors; System requirements such as software and hardware specifications, system responses, or system actions, clarity of the output and usefulness of the system

Business requirements. Ability of the mobile app to approve workflows and authorization levels *

- ◯ Very high
- ◯ High
- ◯ Average
- ◯ Low
- ◯ Very low

User requirements. The ability of the mobile app to allow the user of the system can do, place an solid waste collection order or browse the online list of waste collectors *

- ◯ Very high
- ◯ High
- ◯ Average
- ◯ Low
- ◯ Very low

Administrative functions. The ability of the routine things the system is doing, such as reporting. *

- ◯ Very high
- ◯ High
- ◯ Average
- ◯ Low
- ◯ Very low

System requirements. The ability of the application to function in your handset such as operating system and hardware specifications, system responses, or system actions *

- ◯ Very high
- ◯ High
- ◯ Average
- ◯ Low
- ◯ Very low

Clarity of the output of the mobile application *

- Very high
- High
- Average
- Low
- Very low

The need of support and technical assistance in using this mobile application *

- Very high
- High
- Average
- Low
- Very low

Usefulness and helpful of the mobile application *

- Very high
- High
- Average
- Low
- Very low

Internet connectivity works perfectly with the mobile app *

- Very high
- High
- Average
- Low
- Very low

Willingness to use the app and recommendation to others *

- Very high
- High
- Average
- Low
- Very low

Submit

Page 1 of 1

Clear form

(b)

ZoaTaka Technical Evaluation Questionnaire

My name is STANLEY ISAAC MANYONYI, I am conducting research on Developing Mobile Application for Solid Waste Management as a Project Report Submission in Partial Fulfillment of the Requirements for the Degree of MSc. IN EMBEDDED AND MOBILE SYSTEMS of the NELSON MANDELA AFRICAN INSTITUTION OF SCIENCE AND TECHNOLOGY, Arusha, Tanzania.

This questionnaire is designed to facilitate the assessment of the developed mobile application solid waste management service in Shinyanga Municipality. Technical evaluators are requested to rate each of the presented aspects into a scale of either Very High, High, Average, Low or Very Low. The aspects to be evaluated by technical experts are Accessibility, Scalability, Usability, Consistency, Navigation, Feedback, Performance and Security

Ability of the mobile application to be accessed/availability/reliability, What are the uptime requirements? Does it need to function 24/7/365? *

- (●) Very high
- ( ) High
- ( ) Average
- ( ) Low
- ( ) Very low

User friendliness/usability of the mobile application. This focuses on the appearance of the user interface and how people interact with it. What color are the screens? *

- (●) Very high
- ( ) High
- ( ) Average
- ( ) Low
- ( ) Very low

Scalability of the mobile application, as needs grow, can the mobile application handle it? *

- (●) Very high
- ( ) High
- ( ) Average
- ( ) Low
- ( ) Very low

Consistency of the mobile application. If a system has at least one solution

- (●) Very high
- ( ) High
- ( ) Average
- ( ) Low
- ( ) Very low

Clear selection

Ability of the mobile application to be navigated *

- (●) Very high
- ( ) High
- ( ) Average
- ( ) Low
- ( ) Very low

Ability of the mobile application to give feedback *

- (●) Very high
- ( ) High
- ( ) Average
- ( ) Low
- ( ) Very low

Performance. How fast does it need to operate?

- (●) Very high
- ( ) High
- ( ) Average
- ( ) Low
- ( ) Very low

Clear selection

Security. What are the security requirements, both for the physical installation and from a cyber perspective?

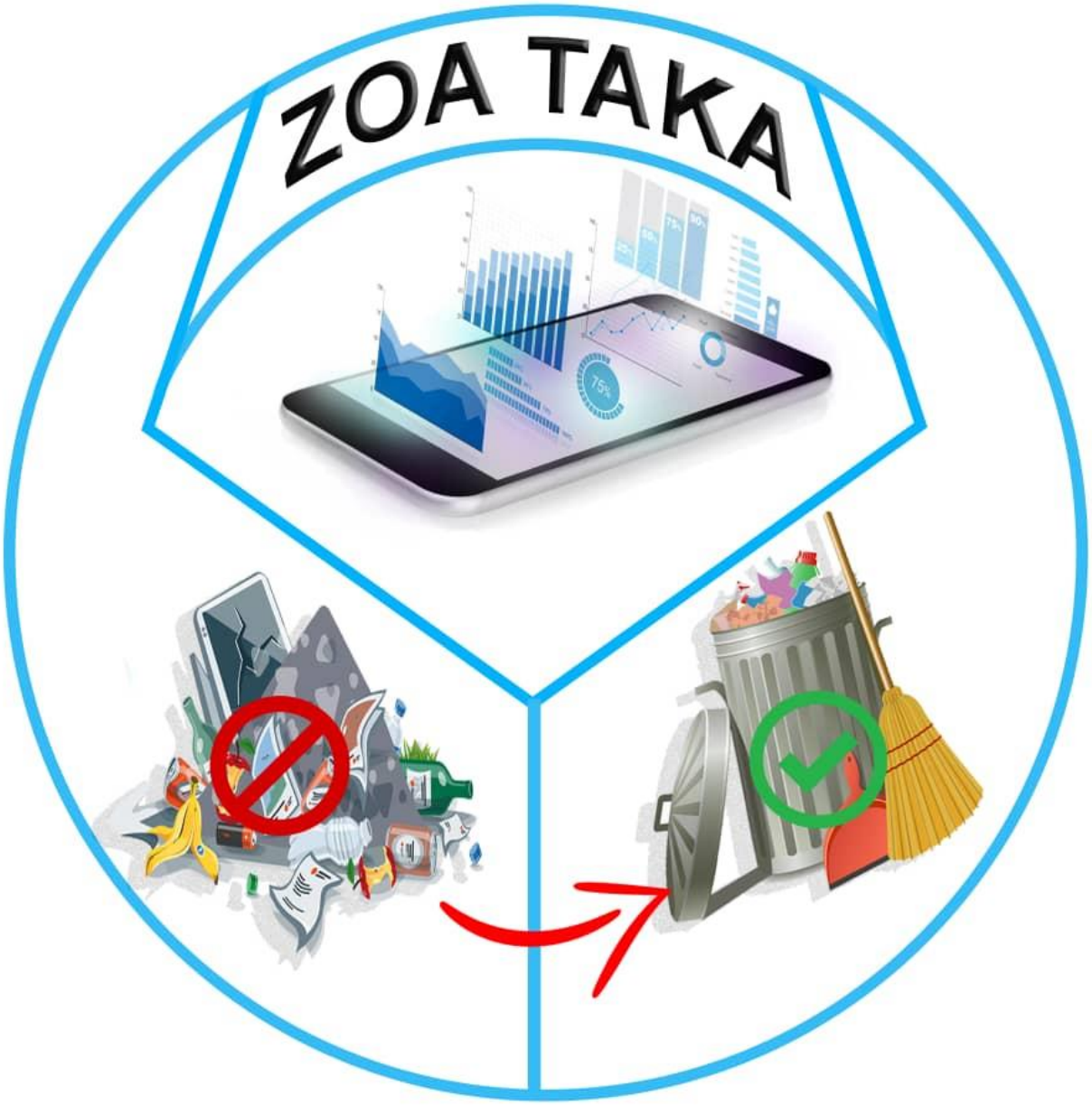
- (●) Very high
- ( ) High
- ( ) Average
- ( ) Low
- ( ) Very low

Clear selection

Submit

Clear form

Appendix 4: The Logo of Zoataka App



Appendix 5: XML codes for collector's revenue report

```
<?xml version="1.0" encoding="utf-8"?>
<LinearLayout xmlns:android="http://schemas.android.com/apk/res/android"
    xmlns:app="http://schemas.android.com/apk/res-auto"
    xmlns:sign="http://schemas.android.com/apk/res-auto"
    xmlns:tools="http://schemas.android.com/tools"
    android:layout_width="match_parent"
    android:layout_height="match_parent"
    android:orientation="vertical"
    tools:context=".RevenueReportCollectorsActivity">

    <androidx.appcompat.widget.Toolbar
        android:id="@+id/toolbarHme"
        android:layout_width="match_parent"
        android:layout_height="56dp"
        android:layout_alignParentTop="true"
        android:background="@color/colorPrimaryDark">

        <LinearLayout
            android:layout_width="match_parent"
            android:layout_height="30dp"
            android:layout_marginStart="1.3dp"
            android:layout_marginLeft="1.3dp"
            android:layout_marginEnd="1.7dp"
            android:layout_marginRight="1.7dp"
            android:orientation="horizontal">

            <ImageView
                android:id="@+id/imageViewback"
                android:layout_width="wrap_content"
                android:layout_height="match_parent"

android:foreground="?android:attr/selectableItemBackgroundBorderless"
                android:src="@drawable/ic_baseline_chevron_left_24" />

            <LinearLayout
                android:layout_width="match_parent"
                android:layout_height="match_parent"
                android:layout_marginLeft="4dp"
                android:layout_weight="2"
                android:orientation="vertical">

                <TextView
                    android:layout_width="match_parent"
                    android:layout_height="wrap_content"
                    android:text="@string/app_name"
                    android:textAllCaps="true"
                    android:textColor="@color/myWhite"
                    android:textSize="10dp" />

                <TextView
                    android:layout_width="match_parent"
                    android:layout_height="wrap_content"
                    android:layout_weight="1"
                    android:fontFamily="@font/google_sans_bold"
                    android:text="COLLECTORS REVENUE REPORT"
                    android:textAllCaps="true"
                    android:textColor="@color/myWhite"
                    android:textSize="12dp" />

            </LinearLayout>

        </LinearLayout>
```

```
    </androidx.appcompat.widget.Toolbar>

    <ProgressBar
        android:id="@+id/my_progressBar"
        style="@style/Widget.AppCompat.ProgressBar.Horizontal"
        android:layout_width="fill_parent"
        android:layout_height="wrap_content"
        android:layout_marginLeft="5dp"
        android:layout_marginRight="5dp"
        android:indeterminate="true"
        android:progressDrawable="@drawable/prog_color" />


    <androidx.recyclerview.widget.RecyclerView
        android:id="@+id/recyclerCollector"
        android:layout_width="fill_parent"
        android:layout_height="wrap_content"
        android:layout_marginLeft="10dp"
        android:layout_marginTop="10dp"
        android:layout_marginRight="10dp"
        android:layout_marginBottom="30dp"
        android:background="@drawable/card_background" />

</LinearLayout>
```

Appendix 6: Java Activity Codes for the Collector's Revenue Report

```
package com.cloudthinkage.zoataka;

import androidx.appcompat.app.AppCompatActivity;
import androidx.recyclerview.widget.LinearLayoutManager;
import androidx.recyclerview.widget.RecyclerView;
import de.mateware.snacky.Snacky;
import es.dmoral.toasty.Toasty;
import io.reactivex.android.schedulers.AndroidSchedulers;
import io.reactivex.disposables.CompositeDisposable;
import io.reactivex.functions.Consumer;
import io.reactivex.schedulers.Schedulers;

import android.content.Context;
import android.graphics.Color;
import android.graphics.Typeface;
import android.net.ConnectivityManager;
import android.net.NetworkInfo;
import android.os.Bundle;
import android.util.Log;
import android.view.View;
import android.widget.ProgressBar;
import android.widget.Toast;

import
com.cloudthinkage.zoataka.Adapters.RecyclerViewAdapter_RevenueCollector;
import com.cloudthinkage.zoataka.Getter.Getter_RevenueCollector;
import com.cloudthinkage.zoataka.Retrofit.ZoaTakaAPI;
import com.cloudthinkage.zoataka.Utils.Common;

import java.util.List;

public class RevenueReportCollectorsActivity extends AppCompatActivity {
    ProgressBar progressBar2;
    private RecyclerView recyclerCollector;
    CompositeDisposable compositeDisposable;
    ZoaTakaAPI mService;
    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_revenue_report_collectors);
        recyclerCollector = findViewById(R.id.recyclerCollector);
        progressBar2 = findViewById(R.id.my_progressBar);
        progressBar2.setVisibility(View.VISIBLE);

        compositeDisposable = new CompositeDisposable();
        mService = Common.getAPI();

        recyclerCollector.setLayoutManager(new LinearLayoutManager(this,
LinearLayoutManager.VERTICAL, false));
        recyclerCollector.setHasFixedSize(true);

        if (haveNetworkConnection()) {
            getAllCollectorRevenue();
        } else {
            Snacky.builder()
                    .setActivity(RevenueReportCollectorsActivity.this)
                    .setMaxLines(4)
                    .centerText()
                    .setBackgroundColor(Color.parseColor("#FFFFFF"))
                    .setTextColor(Color.parseColor("#FFFFFF"))
                    .setActionText("Retry!")
                    .setActionTextColor(Color.parseColor("#cd201f"))
```

```
                    .setActionClickListener(new View.OnClickListener() {
                        @Override
                        public void onClick(View v) {
                            compositeDisposable = new CompositeDisposable();
                            mService = Common.getAPI();
                            getAllCollectorRevenue();
                        }
                    })
                    .setActionTextSize(20)
                    .setMaxLines(4)
                    .centerText()
                    .setActionTextTypefaceStyle(Typeface.BOLD)
                    .setDuration(Snacky.LENGTH_INDEFINITE)
                    .error()
                    .show();

            Toasty.error(RevenueReportCollectorsActivity.this, "No internet
Check your settings", Toast.LENGTH_LONG, true).show();
            // Toast.makeText(this, "No intenet Check your settings",
Toast.LENGTH_SHORT).show();

        }

    }

    public void getAllCollectorRevenue() {
        progressBar2.setVisibility(View.VISIBLE);
        progressBar2.setIndeterminate(true);
        compositeDisposable.add(mService.getallCollectorRevenue()
                .subscribeOn(Schedulers.io())
                .observeOn(AndroidSchedulers.mainThread())
                .subscribe(new Consumer<List<Getter_RevenueCollector>>() {
                                @Override
                                public void
accept(List<Getter_RevenueCollector> products) throws Exception {
                                    displaygetProducts(products);
                                }
                            }, new Consumer<Throwable>() {
                                @Override
                                public void accept(Throwable throwable) throws
Exception {
                                    Log.e("nullresp1212", "Error :" +
throwable.getMessage());
                                    progressBar2.setVisibility(View.GONE);

                                    //Log.e(TAG, throwable.getMessage(),
throwable);
                                }
                            }
                ));
    }

    RecyclerViewAdapter_RevenueCollector productsAdapter;

    private void displaygetProducts(List<Getter_RevenueCollector> products) {
        productsAdapter = new
RecyclerViewAdapter_RevenueCollector(products,RevenueReportCollectorsActivity.
this );
        recyclerCollector.setAdapter(productsAdapter);
        productsAdapter.notifyDataSetChanged();
        progressBar2.setVisibility(View.GONE);
    }

    private boolean haveNetworkConnection() {
```

```
        boolean haveConnectedWifi = false;
        boolean haveConnectedMobile = false;

        ConnectivityManager cm = (ConnectivityManager)
getSystemService(Context.CONNECTIVITY_SERVICE);
        NetworkInfo[] netInfo = cm.getAllNetworkInfo();
        for (NetworkInfo ni : netInfo) {
            if (ni.getTypeName().equalsIgnoreCase("WIFI"))
                if (ni.isConnected())
                    haveConnectedWifi = true;
            if (ni.getTypeName().equalsIgnoreCase("MOBILE"))
                if (ni.isConnected())
                    haveConnectedMobile = true;
        }
        return haveConnectedWifi || haveConnectedMobile;
    }

}
```

POSTER PRESENTATION