Design and development of USSD-based system for solid waste management

Faiza Jada Babakano*, Ishaq O. Oyefolahan, Hussain A. Zubairu and Stella O. Etuk

Department of Information and Media Technology,
Federal University of Technology,
Minna, Nigeria
Email: faiza.bkano@futminna.edu.ng
Email: o.ishaq@futminna.edu.ng
Email: abu.zubairu@futminna.edu.ng
Email: abiolastella@futminna.edu.ng
*Corresponding author

Abstract: As the world population grows so are the wastes that are produced. Most of these wastes are hazardous and poses health challenges to the environment. Proper waste management is key towards ensuring that the human environment is preserved for the good health and well being of its inhabitants. Unfortunately, municipal solid waste disposal practices in most Nigerian cities fall short of the minimum standard expected. This research therefore, designed a novel ICT-based framework for waste management and consequently developed a simulation of USSD-based communication and payment processes between the different stakeholders involved in waste management. Based on the performance of the simulated system, it is obvious that waste management can be made easier, transparent, more organised and sustainable.

Keywords: solid waste; unstructured supplementary service data; USSD; smart systems; charge as a service; CAAS; mobile operations; waste management; framework; simulation; design; development; payment; communications.

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Biographical notes: Faiza Jada Babakano is an Assistant Lecturer in the Department of Information and Media Technology, School of Information and Communication Technology, Federal University of Technology, Minna, Niger State, Nigeria. She obtained her BSc in Computer Science from the American University of Nigeria (2009) on full tuition scholarships and MTech in Image Processing/Data Mining from the Federal University of Technology, Minna in 2015. Her research interest includes data mining, community and developmental informatics. She has published in both national and international journals and conferences.

Ishaq O. Oyefolahan is currently a Senior Lecturer at the Department of Information and Media Technology, Federal University of Technology, Minna, Nigeria. Prior to joining his current department, he was an Assistant Professor at the Department of Information Systems, International Islamic University Malaysia. His fields of interest are business intelligence, web and mobile

applications development, utilisation and evaluation, business-IT alignment and knowledge management. He has published several technical papers in international, national journals and conferences.

Hussain A. Zubairu is a Lecturer in the Department of Information and Media Technology, School of Information and Communication Technology, Federal University of Technology, Minna, Niger State, Nigeria. He obtained his BSc and MSc in Computer Science from Ahmadu Bello University, Zaria, Kaduna State, Nigeria. He teaches web design and development, Java programming language, computer architecture and e-commerce. His research interests are knowledge management, machine learning and ICT for development.

Stella O. Etuk is currently working as a Lecturer in the Department of Information and Media Technology, School of Information and Communication Technology, Federal University of Technology, Minna, Niger State, Nigeria. Her first degree was mathematics and computer science. She picks interest in applied mathematics and had her Master in Mathematics (Numerical Analysis) in 2014 from the same University. Her future research agenda include system modelling and data analysis.

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1 Introduction

Waste is arguably one of the biggest global challenges. Municipal solid waste is on the increase every year and the World Bank predicts it to rise from 1.3 billion tons per year to 2.2 billion tons per year by the year 2025 with developing countries facing the greater challenges (Bhada-Tata and Hoornweg, 2012). The same report by the World Bank also projected the cost of managing solid waste to rise from $205 billion to $375 billion annually. Consequently, there is need for innovative and efficient method for municipal solid waste collection and disposal to meet up with the growing population.

There are numerous challenges involved in solid waste collection and disposal, especially in developing countries. Some of the challenges include inadequate waste disposal infrastructure, infrequent collection due to lack of payment for waste disposal services and inaccessibility of remote areas (Rameos et al., 2012). Lot of litters can be found by road sides and in some public places around the globe especially in urban areas simply because waste disposal infrastructure like waste bins and dumpsters are unavailable at necessary locations. This makes individuals to throw their litters indiscriminately in public places. In situations where such facilities are available, the problem of infrequent or in some cases lack of collection of the waste occurs because of ineffective waste disposal mechanism and communication processes.

According to Guerrero et al. (2013) communication transfer between the different stakeholders is of high importance in order to get a well functioning waste management system in cities of developing countries. In addition, financial implications of waste management is a major challenge for both governments and individuals especially in

developing nations, where adequate priority is not given to waste management on the part of government and individuals due to insufficient income . The population in developing countries may not be willing to pay high amount of money for waste disposal because they have basic necessities which they are striving to meet up with. Thus, within these challenges, there is a need for robust and low-cost waste management procedures in major cities of developing nations.

Considering the current penetration rate of GSM around the globe and Nigeria, with over 144 million Nigerians out of an estimated 180 million people connected to telephones as of December 2017 (NCC, 2017). This figure represents a teledensity of 103.61. USSD are value added services provided by mobile operators to automate interactive functional processes. This technology has been applied to Mobile Banking, advertisements etc. Beyond the fact that USSD communication technology is basic and provisional by almost all mobile operators, it is also an easy technology, basic enough for the lay man, affordable in terms of cost and can be customised to cater for different language needs.

Based on the ICT-Based solid waste collection, transfer and disposal framework in (Babakano et al., 2016), this paper presents the design and development of a simulated USSD-based communication and payment system for solid waste collection and disposal. The developed application models the communication processes between waste generators (households and organisations), waste carriers (individual ad hoc staff or private waste carriers) and waste managers.

The rest of this paper is organised as follows: Section two presents the review of current technologies and processes used in municipal solid waste collection, transfer and disposal. Section three discusses the tools and methods used to achieve the simulation of real life solid waste collection, transfer and disposal via USSD-based communication channels. Section four discusses the benefits and implications of the system and section five presents the summary as well as the conclusion.

2 Background of the study

The word Sustainability has a broad connotation and is often used interchangeably with the phrase ‘sustainable development’. In order to make it more concrete, sustainability is often considered from various perspectives mainly the ecological, the economic and the social perspective (Hart and Milstein, 2003; Karen and Daniel, 2011). The concept of sustainability in environmental discourse gained prominence with the report of the World Commission on Environment and Development in 1987; Our Common Future. Its political relevance was established at the Rio Earth Summit in 1992 (Karen and Daniel, 2011). Since then, sustainability had been both a local and global discourse. Individuals, corporate entities, government and non-governmental organisations have taken a lot of sustainability initiatives and policies to make our environment, economy and social life more sustainable. Schools across the globe are introducing the concept of Sustainability in their curricular so as to teach the upcoming generation its relevance and to make them drivers of sustainability (Elina and Daniel, 2014).

Inadequate municipal solid waste management poses sustainability threat to our society, thus waste collection and disposal are the two components in waste management (Nwigwe, 2008) that calls for adequate attention. Waste is usually used to mean by-products of human daily activities which are no longer useful to man. According to

Allaby (1998) it can be defined as any substance be it solid, liquid or gaseous, that remains as a residue or an incidental by-product of the processing of the substance and for which no use can be found for the organism or the system that produces it. Proper and efficient waste management is necessary for hygienic society and for the world as a whole (Bashir et al., 2013). The role of ICT in waste management is gaining prominence and this paper intends to explore deeper into an effective means of exploring ICT for management of municipal waste in Nigeria.

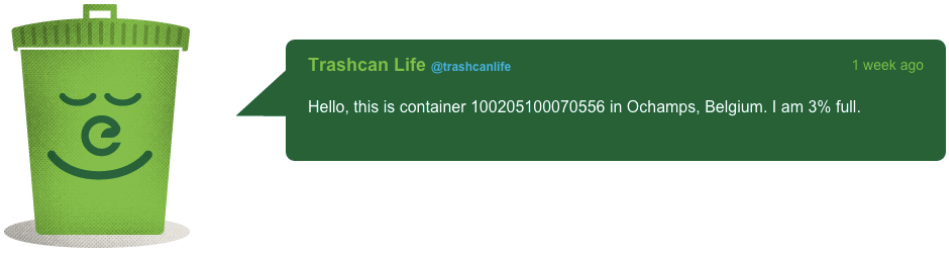
Information and communication technology (ICT) is an umbrella term that includes any communication device or application including TV, radio, computers, handsets, network hardware and software etc as well as the various services and applications associated with them, such as videoconferencing and distance learning (ICT Definition, n.d.). ICT has been argued by some researchers to be the fourth utility of man after housing, water and electricity (Townsend, 2013). Since the inception of the ICT revolution in the early 1990s, it has continued to grow at an exponential rate in both developed and developing countries as conveyed from ICT statistics, "the world continuous to move faster and faster towards a digital society" (ICT Fact and Figures, n.d.).

2.1 Automation of solid waste management

Smart systems are systems that incorporate functions of sensing, actuation, and control in order to describe and analyse a situation, and make decisions based on the available data in a predictive or adaptive manner, thereby performing smart actions (Smart Systems, n.d.). Smart systems initialise a feedback loop of data, which provides evidence for informed decision making (The Royal Academy Engineering, 2012). From available literatures, smart systems like artificial organs are used to save lives and in the transport sector, auto-pilot has been used to reduce traffic accidents.

Smart applications have also been found useful in waste management. Waste management companies like Enevo (Enevo, n.d.) have created innovative IT solutions for collection and disposal of waste. A Trash receptacles use smart wireless sensors to generate fill level data from waste containers. The proprietary dumpster can "talk" to the office of waste collection when it is filled up thereby saving cost and time of trips made by waste collectors. Figure 1 illustrates the waste container fitted with trash receptacle. These sensors can also help the company forecast dumpster filling patterns.

Figure 1 Enevo proprietary dumpster reporting on its current state to the waste office (see online version for colours)



Source: http://www.enevo.com/

Aside the industries, researchers have made tremendous contributions in automating aspects of waste management. Desai and Parimala (2017) presented a problem of collecting and managing waste in cities by checkmating indiscriminate waste disposal. They proposed a model that incorporates geographical position system (GPS), Sensors and closed-circuit TV (CCTV) technology to monitor and automate waste tracking and management. The result of such model is the reduction in the amount of wastes littered around the city.

Boateng et al. (2014) research work considered the social and economic response to solid waste management of the residents of Atonsu in Ghana. They administered questionnaire and conducted interviews. The result showed that Pay-as-you-dump and house payments are the most socio-environmental responses of the residents. However, the correlation between income levels and amount paid for waste disposal is statistically weak; implying that amount paid for waste disposal may not necessarily depend on income levels of respondents. The paper concluded that public education on reduction, reuse, and recycling of solid waste is imperative.

Vélez and Mora (2016) looked into the challenges of waste management in Medelin in Columbia. They used Vensim PLE software to simulate various scenarios; combining both formal and informal processes of waste management. They developed a solid waste management model and conclude that it provides huge benefits related to the social, economic and environmental aspects of the system.

Reliable information and a clear characterisation of the municipal waste generated are important in the development of an effective and sustainable waste management system. Elkhedr (2016) researched into the problem of poor waste management resulting from poor revenue derivation by analysing the revenue of recyclables in wastes collected. The research was conducted through audit of household waste of high income districts. The result showed that the revenue of recyclable gives a surplus over the cost of managing the waste. Such surplus could be added to the waste management cost to enhance the revenue for managing wastes. Thus, the author concluded that information management is a key to solid waste cost and revenue managements.

Ion and Gheroghe (2014) looked at the innovative role of ICT in sustainable waste management. Among the technologies found to be developed and used for sustainable waste management are decision support systems (DSS), remote sensing and geographical information systems (GIS) and GPS for real time monitoring indiscriminate waste disposal.

Effective communication between waste management stakeholders and the development of effective and efficient mode of payment for the services will enhance waste management process better than what is currently obtainable in Nigeria. Therefore, this research introduced the USSD technology which is a more ubiquitous and affordable technology to the waste management chain.

3 Materials and methods

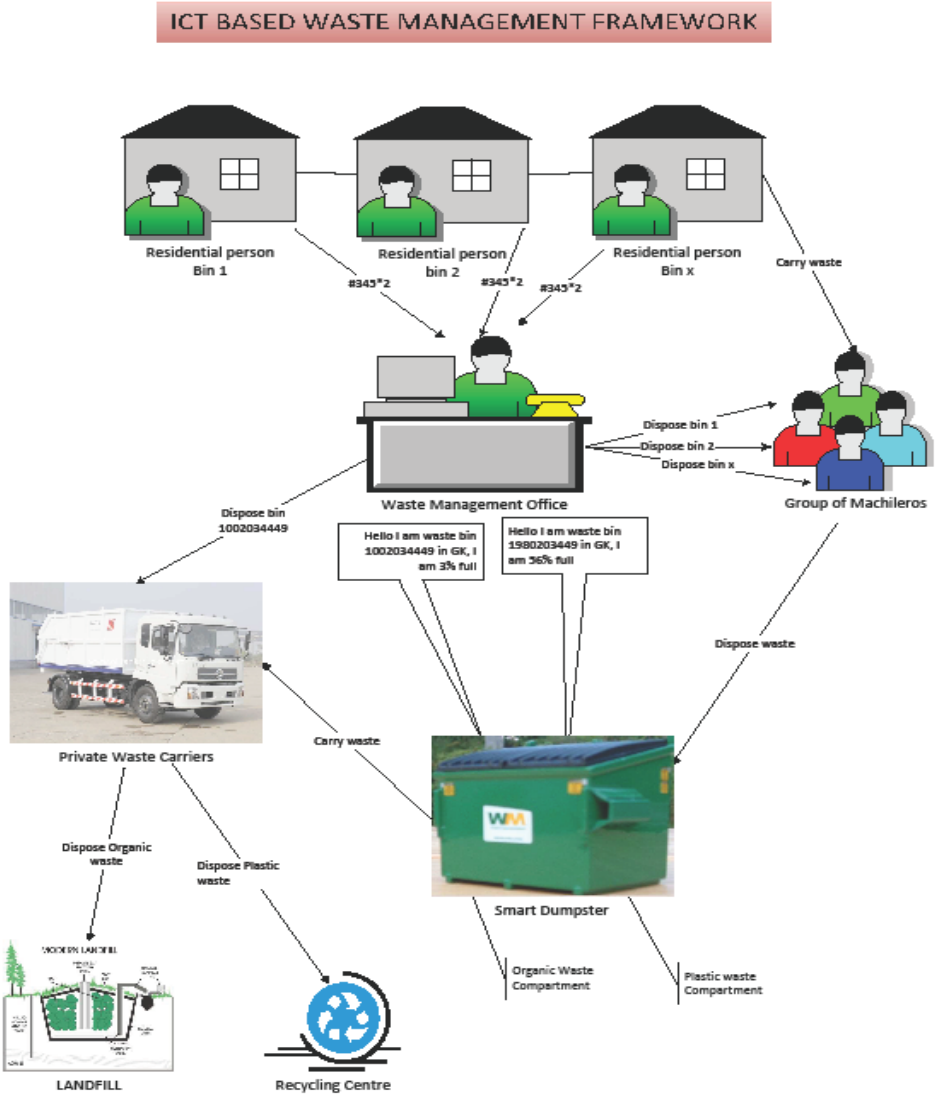
This section discusses the tools and methods used to design and develop an accessible, easy to use, and transparent USSD-based waste management system that facilitate the communication processes and payment services involved in waste management towards effective and efficient waste management. However, since access to USSD gateways of

mobile service providers involves some financial muscles the proposed framework is simulated using open source USSD simulator software – DEVSPACE SIMULATOR.

3.1 Designed framework for USSD-based communication in waste management

The framework employs the use of USSD in managing communication and payment for rendered service between stakeholders. It manages the communication from the point of creation (house hold waste) all the way to the point of final disposal either to the landfill for organic waste or to the recycling centre for plastic wastes.

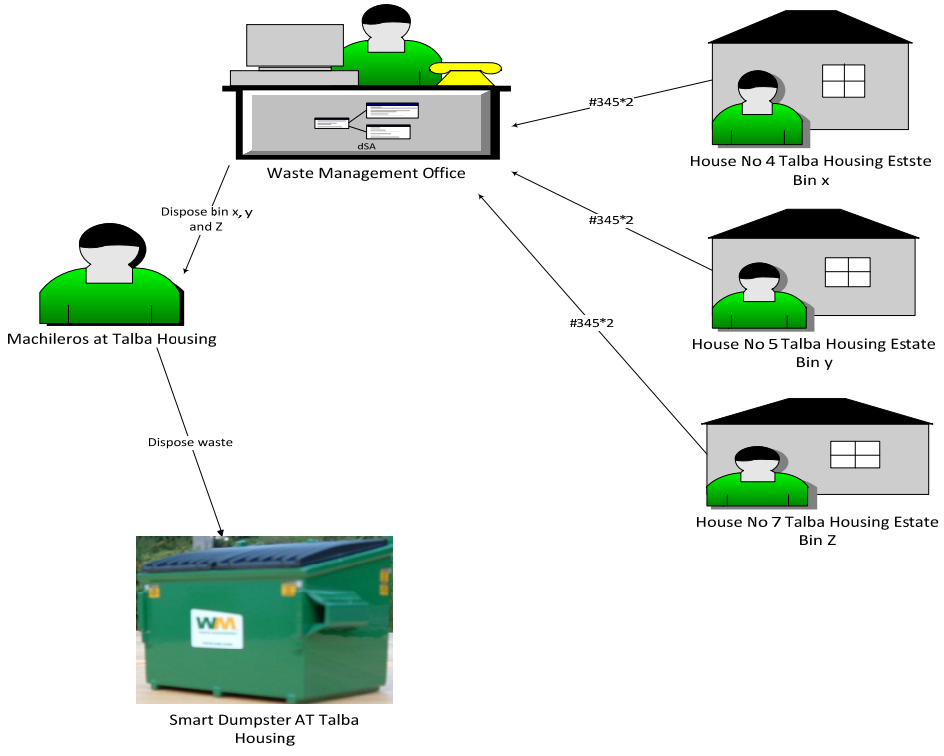
Figure 2 Interactions between entities in the ICT-based framework for waste management (see online version for colours)



The framework starts from the household point of view. There is a USSD code (*333*1# used for the simulation) which households can dial through their mobile phone to alert and request the Waste Management Office (WMO) of the need to dispose their waste. The code is analogous to using **737*2*phone number#* to buy mobile phone credit via the Nigerian-based Guaranty Trust Bank (GTBank). In this scenario, a small token of money is expected to be charged from the household for the waste disposal services. The service will only go through, if the user has enough credit that can pay for the service in his mobile phone. For instance if a client has ₦100 and the payment for the waste disposal is ₦500, the application will return failure due to insufficient balance.

Prior to this, the client is expected to have registered with the waste management office using his/her mobile phone or physical presence in the WMO office. In the process of registration, the client's home address or organisations address is tied to the provided phone number. In this way, the phone numbers are used as the unique identifier for the locations where the services are needed.

Figure 3 WMO (optimisation software) assigning mochileros based on their distance from request (see online version for colours)



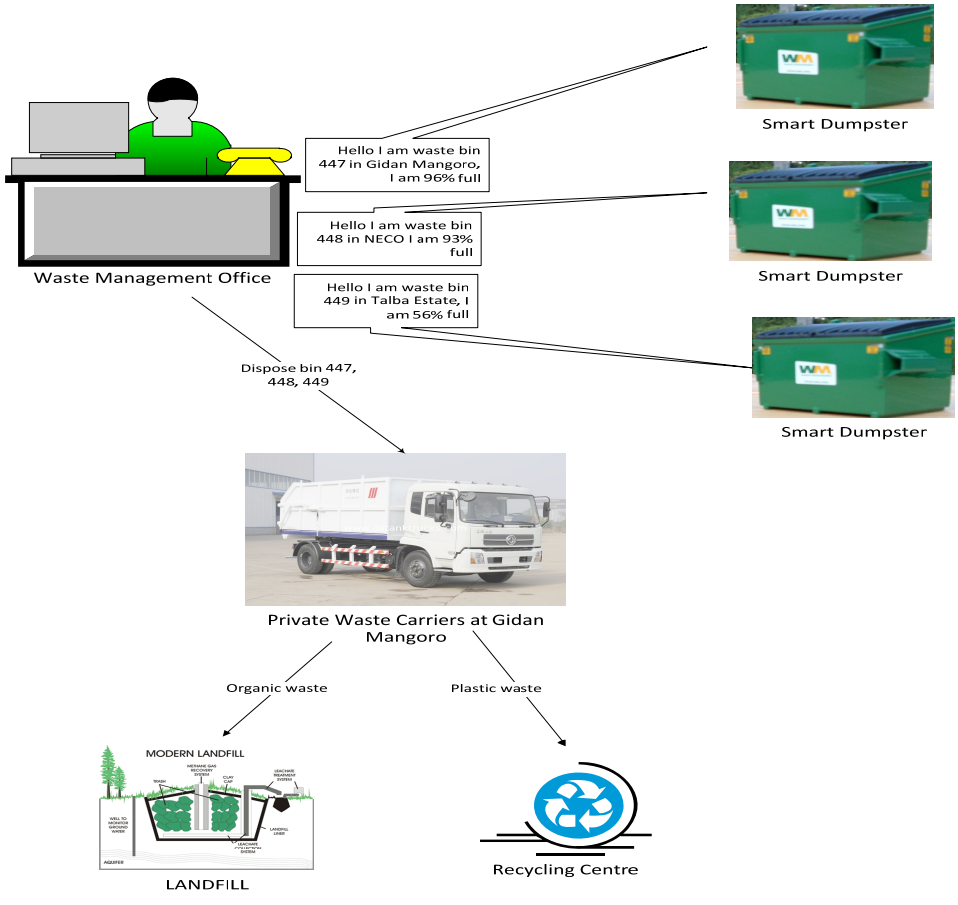
On receiving the alert/request from various households, the WMO application module of the system determines the identity and location of each request by matching the phone number with the address from the database and based on that, the system automatically assigns a particular waste collector (*mochileros*) for the household. The mochileros are notified via SMS which is also automated. The mochileros are registered adhoc staffs of the WMO. The WMO have record of the addresses and locations of the mochileros as

well as the clients in its software module that interacts with the USSD module. The WMO application software assigns the mochileros to the appropriate household based on their distance to the households. The whole framework is illustrated in Figure 2.

In the event where requests are coming from multiple households that are close to each other, a single mochilero is automatically assigned to those number of households by the system for optimisation reasons. Figure 3 illustrates this scenario whereby all requests coming to the WMO are from close houses in the same estate hence a single mochilero is assigned to serve all the three houses because of their proximity.

The waste collected by the mochileros is dumped in the nearest roll-on or dumpsters preferable a street/community dumpster. These dumpsters have two compartments; one for organic waste and the other for plastic waste. The mochileros ensure that the waste are sorted into plastic or otherwise and dump them appropriately in to the dumpster. The dumpsters are fitted with trash receptacles that alert the WMO of their weight or volume. This is a technology that helps the WMO to smartly determine when trashcan/dumpster is filled up and ready for collection.

Figure 4 Optimisation software assigning dumpers based on their distance from request (see online version for colours)



Based on the location of dumpsters that are filled up, the application software in the WMO will assign appropriate private waste carriers to empty the dumpsters into the land fill or to the recycling centre. The private waste carriers are similar to the mochileros but have vehicles (dumpers) to empty roll-ons/dumpsters in a street or neighbourhood instead of households. With their records at the WMO, waste carriers will be assigned dumpsters that are closer to their locations or even to multiple dumpsters if there are some filled ones in the same locality. This is illustrated in Figure 4.

Figure 4 shows filled smarts dumpsters from three different but close localities reporting to the WMO. Due to the proximity of the three dumpsters, a single private waste collector is assigned to empty all of them. Upon receiving the message from WMO, the private waste collectors will empty the assigned roll-on to the landfill and/or to the recycling centre as the case may be. In either case the *mochileros* and the private waste collectors will report to the WMO for their remunerations.

In addition, the system allows customers to complain or give some feedback as part of the USSD options.

3.2 Payment and rendered service confirmation

After the deductions of a client's money for the service requested, a one time password (OTP) is generated and sent to the number that made the request. The mochileros/waste collectors need to get the OTP from the client to confirm via the USSD that the service rendered was satisfactory. The clients give the OTP to the mochileros or waste carriers and such a person confirms he/she rendered the services by inputting it via USSD using the confirm request menu. After the confirmation, the WMO module acknowledges that a particular service had been rendered and pays the mochileros/waste collectors accordingly. This process is to forestall any act of irregularities or cheating from either party.

3.3 Simulated software

The designed ICT-based waste management framework is illustrated in Figure 2, it consists of two software applications that interact to produce the required result. The first software which is the scope of this paper is the mobile-based application that involves USSD-based services that facilitate communication and payment between waste producers and the waste collectors. The second software is the module which the WMO use to monitor and track transactions between the parties aforementioned and mediate if there are complains.

USSD is interactive menu-based access to a range of services without any software installation on handset or SIM card. The USSD was chosen because of its platform independence, ease of use and ubiquitous quality. Unlike other waste management applications used in the developed nations, this solution does not require internet connection or expensive phones like android or iOS phones. This makes it a good choice for everyone.

A number of other USSD simulating environments like LIBict and MChoice were reviewed but DEVSPACE simulator was chosen because it combines all the mobile services on one platform like SMS, USSD, location-based services (LBS), charge as a service (CAAS) and Subscription. The simulator creates a virtual environment for content providers (CP) to test the created applications before implementing it in the real-world

system. The applications can be tested with actual validations using the simulator. A number of scripting languages work well in the DEVSPACE environment; however, PHP is used in this research.

3.4 System requirements

Considering the fact that the model was created for efficiency and simplicity to be practicable especially in the developing countries, the requirements for the system are affordable. Clients need to register into the system either using the USSD option of registration or can go to the WMO office and register. In addition, the mochileros and the trash vehicle owners (waste carriers) also need to register with the waste management office and possibly assign them to particular axis or region of operation. For instance a particular waste carrier can be assigned to a particular street, so any time request for disposing dumpsters come from that street, that waste carrier is notified because that is his/her axis.

For the issue of USSD payment services, collaboration/partnership between the WMO and the mobile operator's needs to be established to use mobile credit cards as a means of payment. Quick teller and the banks can be engaged directly for deductions from the bank accounts as an alternative. In such scenario, there is needed to be an agreement/collaboration between the WMO, the bank and the quick teller companies. Quick teller gives a convenient access to an array of services including recharge, bill payments, donations and payment for government services. Therefore, it would a good option for waste management payment services.

4 Results

The simulation of the software was done using the methodology discussed in section III. The system is simulated using DEVSPACE simulator. Figure 5 shows the different services provided by the application and the sequences of actions carried out to successfully complete a transaction or use cases by different users of the system.

The default screen the customer first sees after dialling the service code:*333# contains all the services the customer can engage using the application. The default screen has welcome to SWMO press 1 to request service, 2 to confirm service, 3 for feedback, 4 for office location, 5 to register and 6 to exit.

Request Service: This is a use case that is carried out by the client. A client is successfully taken through the USSD prompts to request for a waste disposal services. On clicking 1 from the home screen the 'request service' screen shows options as follows:

1 for mochileros

2 for 10 ton truck

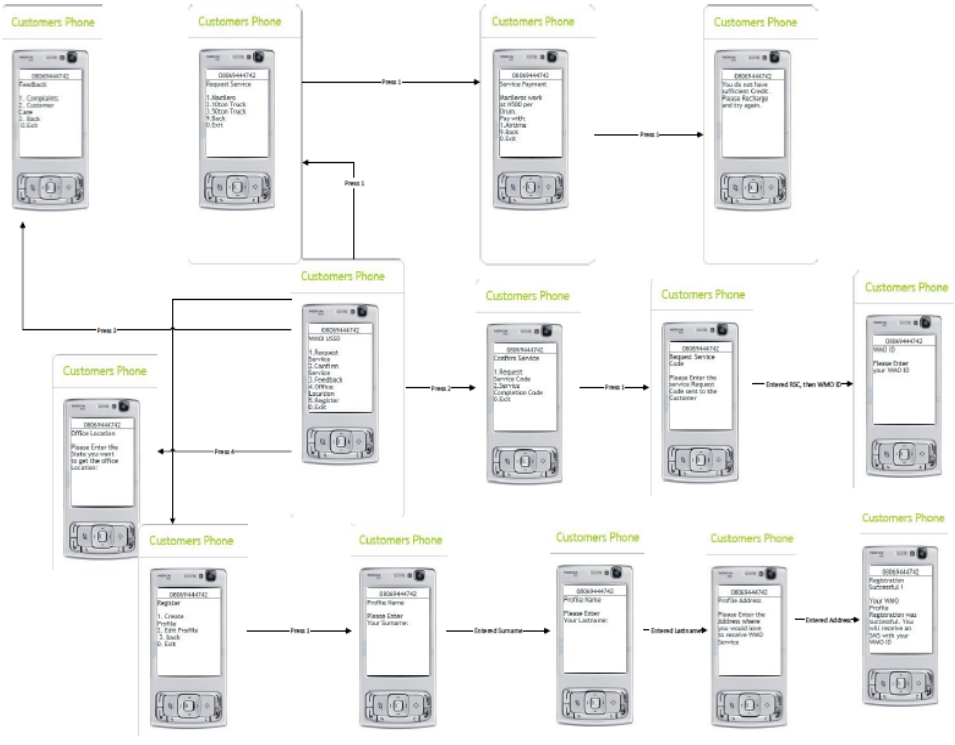
3 for 50 ton truck

4 for going back

5 to exit.

Options 1–3 are sample services provided by the WMO and a client can select any of the options based on the quantity of waste he/she wants dispose. Back returns the user to the previous screen while exit quits the services.

Figure 5 Snap shots of the simulated system with different use cases carried out (see online version for colours)



Mochileros: If the user selected 1 for the mochileros service option from the previous screen a message "Mochileros works at ₦500 per Hour" is displayed with the options press 1 to continue the request for the service, 2 to return to previous screen and 3 to exit the service. On selecting the continue option of the screen the client is prompted to provide the number of mochileros needed. The input takes only numeric values. The next screen returns the calculated cost for the service requested and provides the user payment options of either airtime or bank. 'Back' returns the user to the previous screen and 'exit' quits the service. The next screen displays the request status, either successful or unsuccessful based on the availability of sufficient fund for the transaction. Thereafter, auto generated SMS is sent to the customer, containing the service confirmation code (OTP) to be used to confirm the completion of the service.

Confirm service: This is a use case that is carried out by the waste collectors; the mochilero and the vehicle waste collectors. After rendering the service, the waste collector is given the OTP code by the client that requested the service as a proof that the service was carried out satisfactorily. The waste collector is then required to provide the code to the WMO via the USSD application. The mochileros or the waste collector (WMO agents) chooses the second option from the home screen to confirm the services. The next screen prompts the WMO Agent for his/her ID and then the OTP. A notification

screen of either successful or unsuccessful service code confirmation will be displayed. This enables the WMO to know the agent that responded to the request and that the agent has done the Job.

Feedback: The 3rd option from the home screen is the Feedback. Upon dialing 3 after the home screen, a new screen displays options for complaints (pressing 1) and option for customer care (pressing 2). Complaints option sends a customer's complaint regarding some service where the screen takes in the complaint of the customer as alpha-numeric input with limitation of 180 character space. After submitting, the screen returns the status of the complaint submission, either successful or unsuccessful.

Customer Care option provides a call-out service for phone call to the WMO office customer care desk. The screen also provides option for main that returns the user to the home screen and exit to quit the service.

Office location: This is another service available to the customer to enquire about office location. It is the 4th option on the home screen. This option prompts the user for the particular state of the Federation (Nigeria) and to show the location of the office. If the user's inputs are invalid, the same screen prompting the name of the state is returned. The resulting screen shows the office location in the state chosen by the user with options of exit or returning to the home screen.

Registration: The last service option on the home screen is the option of registration of a client via the USSD application. On dialling 5 to choose option 5 and register, the user sees sub options such as 1 for create, 2 for edit, 3 for back and 4 for exit. *Create*: creates a new user profile *edit*: edits existing user data *main*: returns to the main screen and *exit*: quits the service. Upon choosing create option, the users registration details including the surname, first name, State, local government area (LGA), house number and street number are all prompted for and provided to complete the registration. Upon successful registration, an auto generated SMS is sent to the customer containing His WMO ID.

The simulated software successfully carried out all the aforementioned services (use cases) for the clients and the WMO agents on the DEVSPACE simulation environment.

4.1 Merits of the framework

A lot of benefits can be outlined from this ICT-based framework and they include but not limited to the following:

1 Effective communication process in waste management: among the challenges of waste management is the communication gap between the different stakeholders. The developed system bridge this gap by bringing about easy and effective communication among different stakeholders involved in waste management process.

2 Employment opportunities for mochileros and private waste collectors: with persistent rise in the unemployment figures in Nigeria, this model will provide employment for private waste collectors and the mochileros.

3 Structured and organised framework that eliminate the challenges of going from house to house to collect money for waste disposal services, rather people pay instantly when they make request to the waste management office. It is pay per

service, hence eliminates the problem of payment delays or lack of will to pay for the service.

5 Summary and conclusions

Waste management in Nigeria has not been given proper priority going by the way waste are collected and disposed. Generally speaking, more efforts are required from individuals, private organisation and government; so that waste can be properly managed and disposed effectively particularly in congested urban areas. Challenges arise either from the government, the households or from waste management contractors that hinders the smooth running of the processes.

Due to lack of proper waste management process, a lot of waste gets accumulated for days which constitute health challenges to the environment. In few cases where they are collected they are mound up in a certain location with no plan as to when to properly dispose them via incinerating or recycling. However, in some satellite areas where the nation's elites reside or places regarded as residence for the people up the social ladder, government through their agency go to collect solid waste from residents of such areas, or through the residents' efforts. Alternatively, most state in Nigeria have agencies that are responsible for moving from one part of the town to the other to pack waste wherever they are accumulated for proper disposal, but this services do not come as often as required by the citizens. Such agencies only carry out such task when it has become an eyesore or probably when it is perceived that some kind of highly placed public office holder will take that route.

The designed and simulated USSD-based communication and payment services for the waste management processes in this paper will help in tackling many of these challenges caused by ineffective and unorganised method of waste management services. The solution also helps in eliminating much of the backlogs as well as creating benefits that include employment opportunities, transparent and effective processes.

The findings from this project reveal that municipal solid waste management can be effectively improved by creating an effective means of communication and payments modality. The future work will focus on the creation of the WMO module that interfaces with USSD application for monitoring and customer feedbacks. In addition, possible incorporation of geographic information systems into the model to monitor indiscriminate waste disposal in localities and take appropriate actions could also be considered.

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