



## ICT-Based Framework for Solid Waste Collection, Transfer and Disposal

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**Abstract**—As the world population is growing so is the waste that we produce. Most of these wastes are hazardous to the environments and hence causes sustainability challenges to the environment. Proper waste management is key in ensuring the health and well being of any environment. This paper explored the need for proper waste disposal, its challenges and prospects. It then demonstrated the role of ICT in providing effective communication process for solid waste collection, transfer and disposal by proposing a novel ICT-based framework for that.

**Keywords**—solid waste; ICT-based framework; smart systems

### I. INTRODUCTION

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 [1][2]. The concept of sustainability gained currency with the report of the World Commission on Environment and Development in 1987, Our Common Future and its political relevance was established at the Rio Earth Summit in 1992 [2]. Since then, sustainability had been both a local and global discourse. Individuals, corporate organizations, government and non-governmental organizations 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 to teach the upcoming generation its relevance and to make them drivers of sustainability in the various responsibilities they find themselves in the future [3].

Solid waste management is a key sector that poses sustainability threat to our society. Waste collection and waste disposal are the two components in waste management. Waste management especially in municipalities is a major challenge to people and the government. Despite the challenges of waste management there also lots of prospects. The role of ICT in waste management is gaining prominence and this paper intends to explore deeper into that.

This paper advocates the use of ICT-based framework for monitoring and managing waste disposal in Nigeria. This framework includes the interactions of technological components and services like Geographic Information Systems (GIS), Internet of Things (IOT), Machine to Machine Technology (M2M) and GPS (Geographic

Positional System) for georeferencing. These combinations of ICT based technologies would be employed to better manage wastes in our communities.

### A. Background

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 [4]. ICT has been argued by some researchers to be the fourth utility of man after housing, water and electricity [5]. Since the inception of the ICT revolution in the early 1990's, ICT has continued to grow at an exponential rate in both developed and developing countries as conveyed from ICT statistics in [6] and "the world continuous to move faster and faster towards a digital society" [6].

Waste can refer to substances that we produce from our daily activities which are no longer useful to man. According to [7], it can be defined as any substance be it solid, liquid or gaseous, that remains 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. The problem of waste management has been categorized in to two parts: collection and disposal [8]. The importance of proper waste management, especially waste disposal cannot be overemphasized because of the individual and communal health hazards associated with poor waste disposal.

### B. Challenges in Solid Waste Management

Some of the challenges in waste disposal include inadequate number of waste disposal infrastructure, infrequent collection due to lack of payment for waste disposal services and scarce access in remote areas.[9] Lot of litters can be found by road sides and in some public places around the globe especially in urban areas. Waste disposal infrastructure like waste bins and dumpsters are not provided at strategic locations for easy waste disposal. This makes individuals to throw their litters indiscriminately in public places. In situations where governments make available such waste disposal infrastructure, the problem of infrequent or in some cases lack of collection of the waste occurs because of ineffective waste disposal communication processes. According to [10], communication transfer between the different stakeholders is of high importance in

order to get a well functioning waste management system in the cities in developing countries. Thus, there is a need to find sustainable solutions to the challenges facing waste disposal.

### C. Prospects in Solid Waste Management

A lot of prospects in waste management abound in the literature. Amongst them are involving communities in decision making about waste disposal. A typical instance is the employment of *machileros*; people with backpacks collecting waste from house to house and thereby employing labour.

Another prospect is the increase in the provision of the waste disposal infrastructure including the dust bins, the giant roll-in containers at strategic positions in societies and campuses. Those containers can as well be monitored technologically (georeferencing) using GPS or other GIS systems [9].

Educational campaign is not left out in the prospects of solid waste management. Some societies are developing educational programs on the needs and how to manage waste properly for schools and even neighborhoods. Typical instance is the student environmental club at American University of Nigeria (AUN) in Yola that organizes litter campaign on the campus and the neighboring environments to clean up the litters and demonstrate good waste disposal habits [11]. This is shown in Figure 1 below.



Figure 1. Litter campaign in progress by AUN student environmental club (Source: AUN sustainability report 2014)

Recycling is also an important aspect in waste management given that it will reduce the volume of waste going into the landfills every day. It also reduces the hazards caused by dumping non-biodegradable waste in the landfills.

Recycling thus reduces the environmental impact of the waste at the same improves the sustainability of waste management [9]. American University of Nigeria in Yola (AUN) introduced an initiative named "waste to wealth" (illustrated in Figure 2) that involves local women weaving yarn from plastic bags. The polluting bags were transformed into iPad cases, tote bags and etc, and sold through AUN to generate income for the women [10].

These innovations are a welcomed developments and it is presumed that Information Technology (IT) can play a greater role in supporting the innovations. Smart systems are examples of IT applications that are deployed to give

innovative solutions in addressing our economic, societal and environmental challenges.



Figure 2. "Waste to Wealth" local women weaving, AUN representative selling finished products at crafts fair in Abuja. Source: AUN sustainability report 2014

## II. SMART SYSTEMS

Smart systems incorporate functions of sensing, actuation, and control in order to describe and analyze a situation, and make decisions based on the available data in a predictive or adaptive manner, thereby performing smart actions [11]. In healthcare sector, smart systems like artificial organs are used to save lives and in the transport sector, smart systems like *auto-pilot* have been used to reduce traffic accidents.

Smart applications have also been found useful in waste management. Waste management companies like Enevo [12] 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 3 below illustrates the waste container fitted with trash receptacle. These sensors can also help the company forecast dumpster filling patterns.

Smart applications can also be used in waste reduction by using the right Machine to Machine (M2M) applications that may help in asset and material tracking. The makers of smart refrigerators may use this technology to alert the user on foods that are about spoiling and shortage of necessary items in the fridge [13].

## III. ICT-BASED WASTE MANAGEMENT FRAMEWORK

The ICT-Based Waste Management Framework is a framework that employs the tools of ICT in monitoring and managing waste 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.

The framework starts from the household point of view. There is a code which households can dial through the 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 top up credit in phone lines when using GTBank. In this scenario, a small token of money is expected to be charged from the household for the waste disposal services.

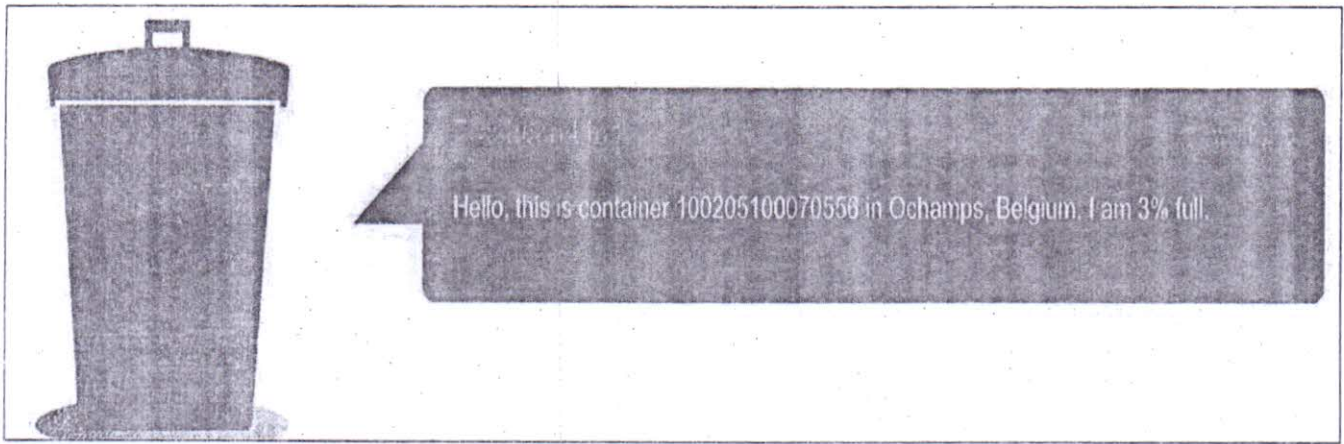


Figure 3. Enevo proprietary dumpster reporting on its current state to the waste collection office (Source: www.enevo.com)

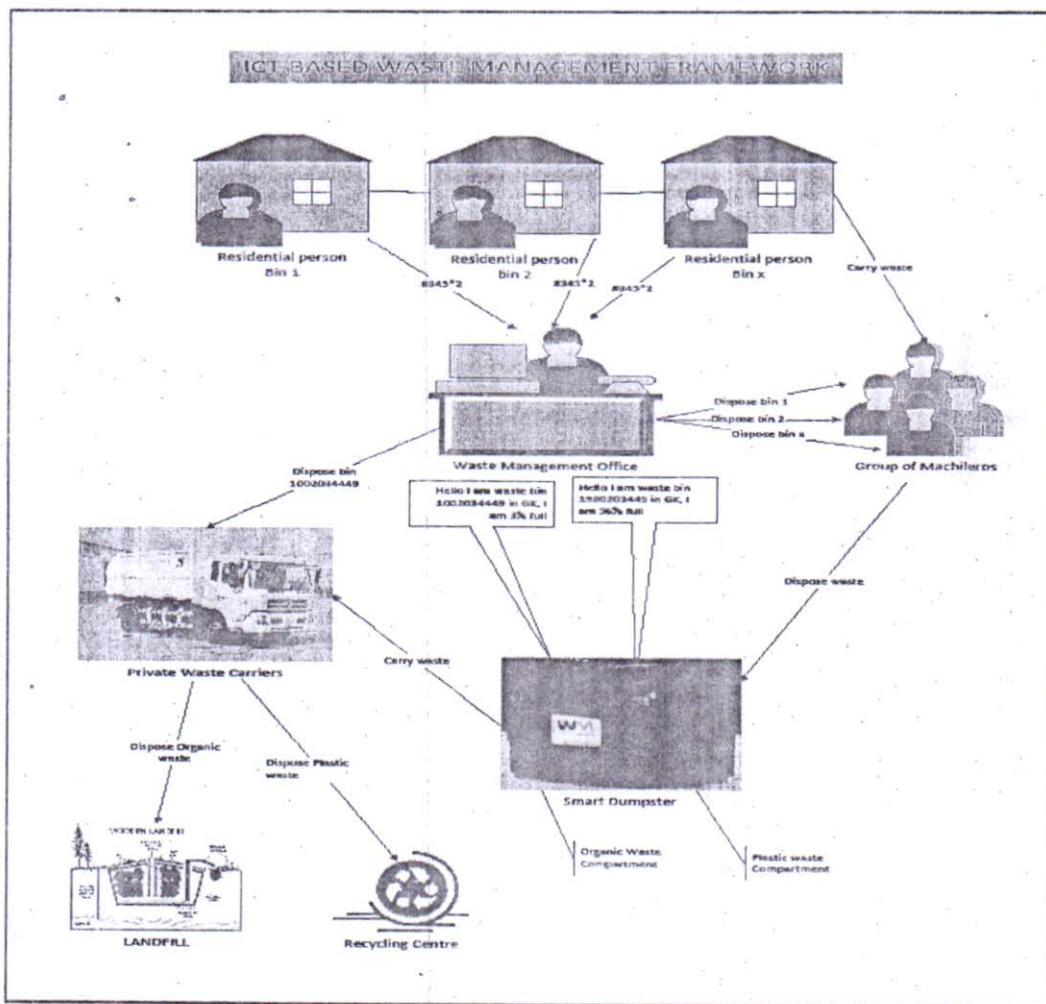


Figure 4. Interactions between entities in the ICT-based framework for waste management

On receiving the alert/request from various households, the WMO determines the identity and location of each request and based on that, assigns a particular waste collector (*machileros*) to a particular household to collect the waste. The machileros are registered adhoc staffs of the waste management office. The WMO have record of the addresses

and locations of the machileros and it is based on that application software, the WMO will assign the machileros to the appropriate household based on their distance to the households. The whole framework is illustrated in Figure 4.

In the case where request are coming from multiple households that are close to each other, a single machilero

would be assigned to those number of households for optimization reasons. Figure 5 illustrates this scenario whereby all requests coming to the WMO are from close houses in the same estate hence a single machilero is assigned to serve all the three houses because of their proximity.

The waste collected by the machileros 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 machileros 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.

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 machileros but have vehicles (dumpers) to empty roll-ons/dumpsters in a street or neighborhood 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 6.

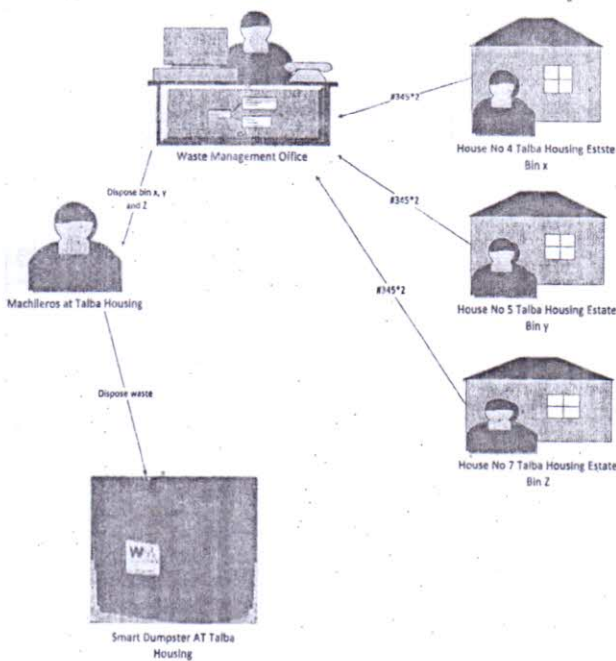


Figure 5. WMO (Optimization software) assigning machileros based on their distance from request

The figure shows filled smart dumpsters from three different but close localities reporting to the WMO. Because of 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 or/and to the recycling centre as the case may be. In either case the machileros and the private waste collectors will report to the WMO for their remunerations.

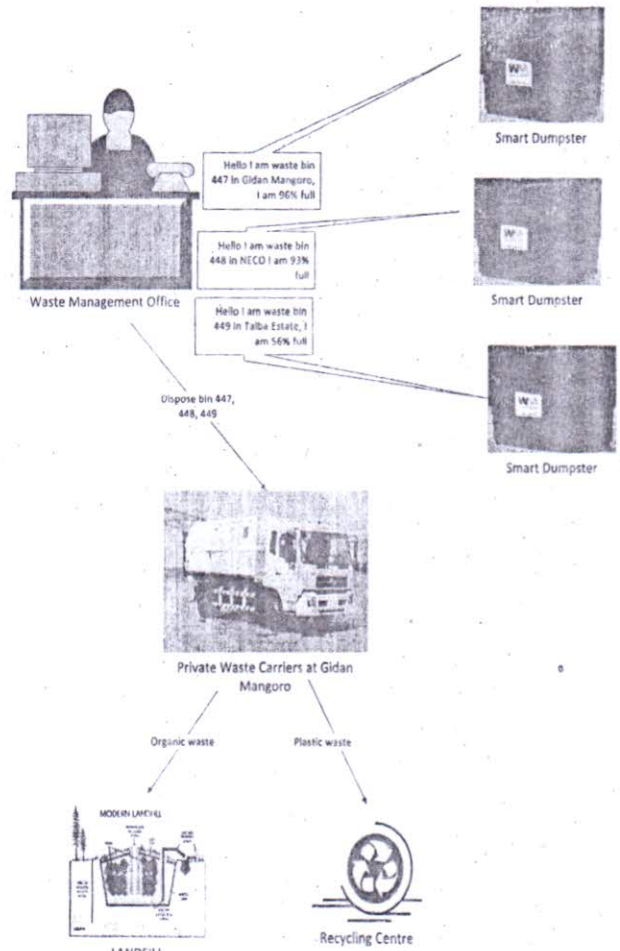


Figure 6. Optimization software assigning dumpers based on their distance from request

#### IV. 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:

- **Effective Communication Process in waste management.** Among the challenges of waste management is the communication process between the different stakeholders,
- **Employment opportunities** for machileros and private waste collectors: With persistent rise in the unemployment figures in Nigeria, this model will provide employment for private waste collectors and the machileros.
- **Structured and Organized Framework** will eliminate the challenges of going from house to house to collect money for waste disposal services, rather people pay instantly through the request they make to the waste management office. It is Pay per service hence eliminates the problem of payment delays and lack of payment.

#### V. CONCLUSION

The present way of waste management especially in Nigeria is not sustainable. Challenges arise either from the

government, from households or from waste management contractors that hinders the smooth running of the process. This paper has proposed an ICT-based framework that can automate and make transparent each of the processes in waste disposal and hence eliminating much of the backlogs as well as creating benefits that include employment opportunities, transparent and effective processes. Future work can include the possible incorporation of Geographic Information Systems into the model to monitor indiscriminate waste disposal in localities and take appropriate actions.

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