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Optimizing Waste Disposal and Collection in Densely Populated Areas Using Embedded System and Android Application

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Abstract

Densely populated areas are the most affected with respect to unorthodox waste disposal practices. The topography of these areas and the lack of proper town planning of building construction makes the terrain difficult to access for waste managers and also provides a lot of dark spots for indiscriminate dumping of wastes. In order to optimize the waste disposal system of these areas, this research uses embedded system and android application, to design and develop a community waste bin that uses sensors, GPS and Wi-Fi communication techniques. In addition to a waste disposal and bin location application was developed using android application. The developed bins would serve as waste aggregation points within densely populated areas while the android application named "Trash Smart" will work to request for waste disposal, locate and navigate to the closest bin using GPS application. The bins would be strategically placed in areas that can be easily accessed by waste manages for collection. In addition, the duo of the bin and app allows waste managers to monitor the bins to know when they are filled and to properly plan their routes for waste evacuation. The adoption of embedded system and android application in waste management will optimize the disposal process of densely populated areas by providing and hygienic and environmentally friendly means of disposal and evacuating waste. Furthermore, the application of these technologies will optimize the operation of waste managers for better efficacy, reduced operational cost and have reliable data expansion of their operations.

Keywords: Community Bin, Android Application, Densely Populated, Waste Management, Waste Managers.

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Introduction

Global population explosion is contributing to the current surge in waste generation (Wong, 2022), thereby posing a lot of challenges to municipal waste managers to collect and dispose this waste (Aliu *et al.*, 2014). Adding to the upraise of waste within homes and industrial areas is the irregular and uncoordinated timing in the arrival of waste collection vans for evacuation of waste. Also the difficult terrains within densely populated areas makes it difficult for waste collection vans to navigate the areas for waste collection (Moruff, 2014). These irregularities in waste collection by waste managers has led to many wastes been emptied in unauthorized open spaces, thus, leading to environmental pollution and possible epidemic (Kadus *et al.*, n.d.).

Managing of millions of tons of waste generated daily within our cities goes beyond manual operations as adequate data sets are required to monitor waste generation, channel route for waste vans and disposal of waste at landfills. Through Embedded Systems, smart bins could be designed with the bins fixed with wireless communication gadgets and sensors that will allow them to be monitor waste bins remotely and plan the routes of waste evacuation vans (Kiran Kumar et al., 2023; Terzi *et al.*, 2021). In addition, through Android

Apps, residents can flawlessly communicate with and monitor the movements of waste evacuation vans, call for waste disposal and locate the nearest IoT bin whenever waste evacuation is not possible (Chetia Patra *et al*., n.d.; Kadus et al., n.d.; Rajavizhi *et al.*, n.d.).

To adequately manage waste within our homes and industrial areas, this paper proposes the use of Embedded Systems in the design of smart bins that can serve as waste aggregation point for close communities to dispose there waste when collection vans fails to show up as at and when required. These bins would be placed where it can be easily assessed for vans and community residence. Also, the paper proposes, the use of an Android app that residents can use to register to a Private Sector Participator (PSP) waste collector, call for waste disposal, monitor the movement of the waste van (Adelakun *et al*., n.d.; Aliu *et al*., 2014; Kf *et al*., 2023; Wong, 2022).

The knowledge of incorporating technology into waste management has evolved over time with various research work have been geared towards improving waste management and ensuring healthy environment through the reduction of air pollution and breeding of bacteria that comes from an accumulation of waste over a long period of time(Aliu *et al*., 2014; Moruff, 2014; Shekari Gandu, n.d.). In tackling the menace of waste, various research have employed technologies like embedded systems, IoT and Wi-Fi to enhance waste management operations through the design of municipal smart waste bins and upheld healthy and cleaner environment (Kumari *et al*., 2018).

The municipal waste bin proposed by (Chetia Patra *et al*., n.d.; Rajavizhi *et al*., n.d.), incorporates a microcontroller based embedded system that coordinates the functions of various sensors that monitors the depth of the waste in the bin, prevents the bin from been filled with rain water, and prevents environmental pollution through the coordinated functions of this sensors. The bin gets monitored by the waste managers through Wi-Fi connection or other data communication technology. The waste managers gets alerted through an alarm triggers once any of the sensors reaches its preset thresholds which could have led to waste overflow, bin been filled with rain water and release of hazardous odors that could impact negatively on the health of the populace.

(Kadus *et al.*, 2020), developed a dustbin using microcontrollers-based platform using Arduino-Uno to interface sensors that monitors levels of waste in the bin and Wi-Fi connection module that is used to communicate with a control unit. The proposed dustbin comprises of a mechanical and electrical components to enhance the operations of the waste bin.

Methodology

The research includes the design and development of a smart community waste bin with forms the hardware architecture of the research design and implementation of an android application code named “Trash Smart” which forms the software architecture of the research.

Architecture of the Smart Waste Disposal System

The developed waste collection system comprises of software and hardware architecture. The software architecture is the development of an android application named ‘Trash Smart’ while the hardware architecture is the development of a microcontroller-based smart community bin. Figure 1, shows the block diagram of the waste disposal system developed using a microcontroller that is interfaced with appropriate electronic circuit and sensors in order to make the bin smart and for the waste managers to remotely monitor and communicate with the bin. To link users (residents) with the bin, the android app is developed to capture and manage user information and for the waste managers to properly carry out route mapping during waste evacuation.

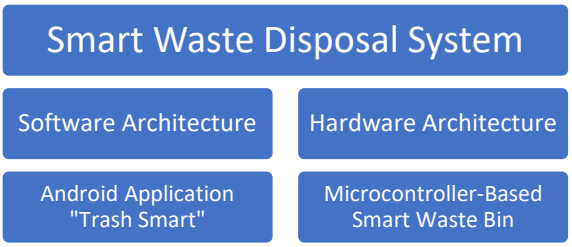

Figure 1: Block Diagram of the Smart Waste Disposal System Architecture

The Android Application (The Software Architecture)

The software is a structure that makes up the Trash Smart mobile application and its components are depicted in Fig. 2.

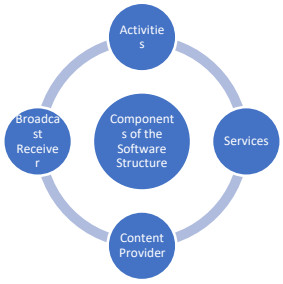

Figure 2: Components of the Software Structure

They include activities, services, broadcast receivers, and content providers. The activities consist of operations that can be performed on the mobile application, these activities are based on functional and non-functional requirements. Services describe what the application has to offer to its consumers which includes durability, flexibility, and much more. The broadcast receiver and content provider consist of requirements for operation, permission, and authentication. The software design component is a structure or terminal within the software development process that ensure the mobile application performs the basic functional and non-functional requirement. These component ensure that information flow properly from the required source to its destination. The diagram in Fig. 2, indicates the communication between the components and how they work together to achieve the set objectives for the app.

The software is further designed to perform based on requirement on functional and non-functional requirements. The functional requirement shown in Table 1, refers to the basic requirement of the software, and are the functions that the software must perform for optimal operations. The functional requirements include User/Admin Login, Dashboard, Register Page, Display Map View, and more. While Non-functional requirements shown in Table 2, are the extra feature that could be added to the software, non-function is not necessary for the operation of software but can be added to the software as an upgrade from the previous version of the software which includes the performance of the software, the GUI, and more.

Table 1: Functional requirement of the Smart Waste Management

S/N	Requirement Description	Priority
1	Register	
	User should be able to register an account with email, password and confirm password.	M
	The system display error message if the compulsory field is not completed.	M

2	Login	
	User should be able to login into the system with email and password. Admin should be able to login into the system with email and password.	M
	The system should display error message if the compulsory field is not completed.	M
	The system should display error message if the user enters wrong information.	M
	User should be able to save their username and password in login page.	O
3	Display Map Views	
	The system allows user gets the route direction from user's current location to dustbin's location.	M
4	Dispose/ Detect Dustbins' Volume	
	The sensor detect the distance of dustbin and calculate in term of volume.	M
	The system able to update the dustbins' status to real-time database.	M
5	Code Lock	
	The system should be able to generate code for the waste bin lock mechanism.	M
6	Logout	
	User able to logout the system.	M

Table 2: List of non-functional requirements of Smart Waste Management System.

S/N	Requirement Description	Priority
1	Operational	
	The system can be accessed via internet.	M
	The system can be used in any android devices.	M
2	Performance	
	The system can be accessed within 24 hours per day and 365 days per year.	M
3	Security	
	The system can be only accessed by registered email and password.	M

Using Google Firebase, the Trash Smart mobile application was developed to communicate with the community bin. Fig. 3a and Fig. 3b, represent a cross-section of the app showing the Home page of the app in the first two images from left and the authentication page, welcome page and the smart bin functions of the app respectively. This app is developed to interface that helps to locate and navigate users to the community waste bin.

Figure 3a: Cross-Section of the Developed Trash Smart App

Figure 3b: Cross-Section of the Developed Trash Smart App

Design and Development of a Smart Community Waste Bin (The Hardware).

The hardware architecture as shown in Fig. 4 is centrally controlled with an Arduino Nano Microcontroller. Arduino is an open hardware development platform that makers, hobbyists, and inventors may use to create and construct objects that interact with the physical environment. Arduino IDE (Integrated Development Environment) is the software for Arduino. Arduino hardware (Arduino NANO) was used as a microcontroller, the primary chip, programmed for it to be able to execute commands and make decisions based on various inputs. The Arduino hardware is capable of ensuring that the devices and components within the system communicate properly with the software. Connected to the Arduino is the LCD Display that shows the current status of the waste bin. The Digital Keypad is attached for users (residents) to enter their unique codes generated at the point of registration. This codes activates the Servo motor connected to the

microcontroller, thus, opening the bin once the correct code is entered. The Ultrasonic Sensor measures the fill level of the bin and compares with the set threshold in order to determine the level of fullness of the bin and to respond accordingly by sending SMS to the operator on the bin level and shutting down the bin if fully filled before evacuation comes. To achieve a proper communication with the bin and the waste managers ESP 32, which is a low cost low-power system on a chip microcontroller is used. This is used to integrate GPS Module and Wi-Fi that gives navigational direction to the user on where to locate the nearest bin and sends bin information via Wi-Fi to waste managers. It also receives bin filled level information and forward same to the waste mangers via the Wi-Fi. The prototype of the proposed waste bin is shown in Fig.5.

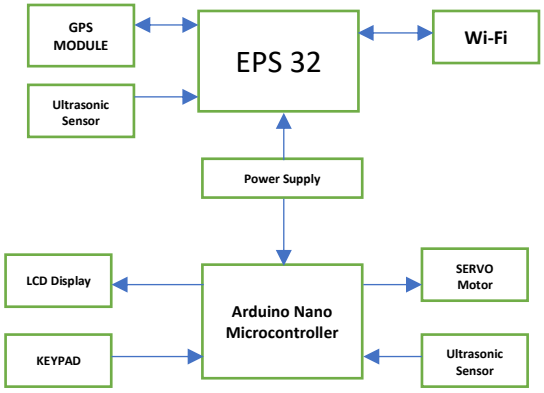

Figure 4: Block Diagram Showing the Waste Bin Architecture

The Operation of the Waste Disposal System

The community waste bin prototype shown in Fig. 5a and fig. 5b, was designed and developed using the architecture shown in fig 4. The design comprises of Ultrasonic sensor for measuring the level of waste in the bin, a GPS module for receiving geo-location data, an LCD unit to display the level of the bin and display data input from the 4X3 Keypad, the Keypad input data into the system which is display on the LCD, Servo Motor for opening the bin and a microcontroller that transfers this data to the database. The Microcontroller collects data from the sensor and transfers the data to Firebase Database using the Internet. Both the microcontroller and android application are connected to the same database for information to be shared between the hardware and software. The bin data is processed on the database and formed into meaningful information which is shown on the Android Application. Management can see the data of all the waste containers on the dashboard of the Mobile Application. Also, the User/ Customer can access the application on their mobile phone/tablet using the internet. Real-time GPS assistance directs them to the location of the waste bin. As they dump their waste and garbage into the containers, the management is also aware of the progress as the waste bins are tracked in real-time. The management staff gets their personalized administration panel over Android Devices which gives them a bird's eye view over the entire operations.

Figure 5a: Prototype of the proposed Community Waste Bin

Figure 5b: Prototype of the proposed Community Waste Bin

Convergence of the Community Waste Bin & Android Application.

The flowchart in Fig. 6, shows the convergence between the waste bin and the android application (app). The app is available for use by the intending subscriber (user) and Administrator (waste managers) and their activities runs simultaneously.

The intending user (a resident of the area) starts by subscribing to the app by downloading and installing the app. The user then proceeds to subscribe to the desired waste manager (Government owned or Private Sector Participator (PSP)). Upon subscription a unique code will be received from the waste managers. This code is required to request for waste disposal or unlock the community waste bin when the need arises.

To dispose a waste, the user logs into the app, then uses the unique code to call for waste disposal from the chosen waste managers. Once the disposal request is confirmed by the managers, a confirmation message is received by the user. Afterwards the user awaits the arrival of the waste evacuation van. However, if the waste van is unavailable, the user turns on the phone GPS to locate and navigate to the nearest community waste bin. Once the bin is locate, the user uses the unique code to unlock the bin and dispose the waste. This completes the activities of the user with the app or the community waste bin.

The administrator (waste managers) logs in to app to verify and approve subscribers and generate subscribers unique codes. Once a subscribe request for waste disposal, the administrator approves and sends a confirmation code to the subscriber. After approval, the administrator dispatches a waste van to the location by providing coordinate of the user location based on subscriber address.

In addition, the administrator monitors the community waste bin through the sensors on the bin. The sensors communicate readings to the waste managers via the Wi-Fi communication technique from which the waste manager gets to know the bins that are filled and requires evacuation. The status of the bin and the activities of the user are monitored by the administration on the app, thus providing real-time information of waste management within every area where the community bin or app are used.

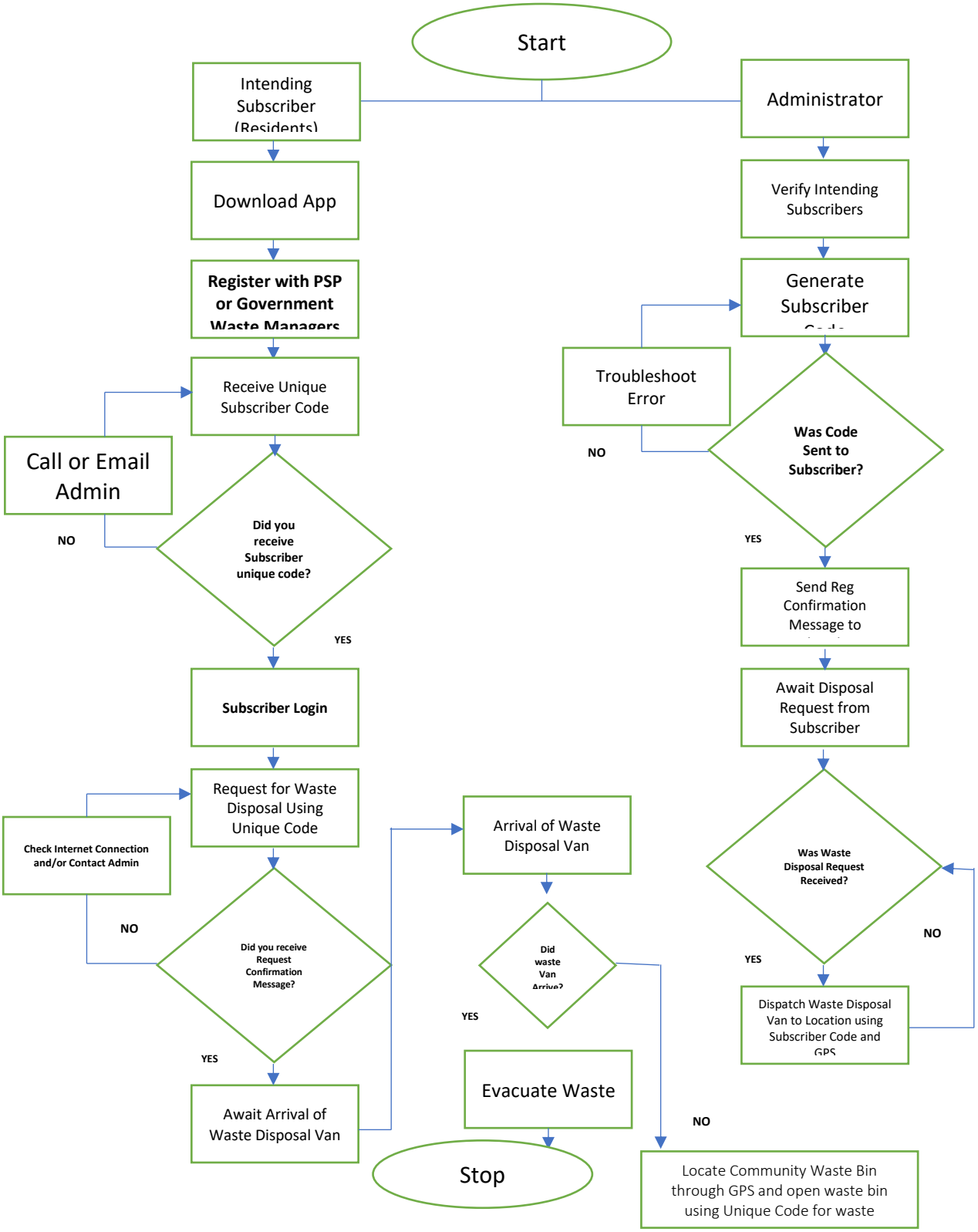

Fig 6: Flow Chart Showing the User and Admin Activities on the App and Waste Bin

Conclusion

Waste management had been a challenging task for government globally but with a more devastating effect within the third world countries. Government within these countries have shown dare moves in changing the trajectory by adopting varying degree of methods to optimize waste management.

The adoption of technologies like embedded system and android applications in waste management system will change the negative images posed by reckless and uncoordinated waste disposal as seen in many densely populated areas as this will allow for proper organizing of the waste disposal channels and coordinated waste evacuation. The use of community waste bin proposed in this research will enhance community hygiene and reduce wild spread of epidemic as waste will be properly concealed within the bin and bacteria spread through flies would be curtailed. Also, adoption of these technologies by waste managers will save them unnecessary cost in deploying waste evacuation vans to locations where they are not needed, thus, providing an adequate route management system based on real-time data of waste evacuation needs.

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