A GIS Based Application, a Tool for Waste Management in Accra Metropolitan Area of Ghana

Stephen DJABA and Priscilla Atta DJABA

Keywords: Waste management, Geographic Information System, Web-based Application, Urban Environment, Recycling

SUMMARY

The production of municipal solid waste has increased noticeably during the recent past due to mounting global population and fast urbanization. Poor management and indiscriminate disposal of waste dominant in developing countries has grown cancerous and become an instrument of climate change related issues. In Ghana, it is common knowledge the grave state of its waste management systems such as the heaps of undisposed waste in drainage systems, overflowing disposal sites and indiscriminate disposal of refuse on its street which leads to a number of environmental issues including the reoccurring floods in the country. This paper therefore attempts to simulate proper waste management techniques with the use of Geospatial tools employed through the development of a web- based application for the Accra Metropolitan Area. It examines the efficient distribution of waste bins, streamlined collection of waste, revenue collection to waste operators and proper disposal methods with the use of a web-based application. In addition, the application provides incentives to ensure waste generated is recycled. Land use/ Land cover change of unregulated disposal sites within the city has also been examined including the ramifications if the necessary systems are not put in place. Geospatial tools and its application have therefore been demonstrated to be an efficient and effective tool to achieve a sustained clean city within Ghana.

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1. INTRODUCTION

The rapid increase in population and urban growth has resulted in the massive increase in solid waste, hence posing a serious threat to the existence of mankind (Allen et all, 1997). Indiscriminate disposal of solid waste products especially in developing countries has grown cancerous on the continent over the years. In low-income regions, it is estimated that over 90% of waste is often disposed in unregulated dumps or openly burned (World Bank Group, 2019). Hence, it is imperative that the appropriate waste management procedures be put in place to make the world a sustainable environment for mankind and future generations. Waste management can however be described as the collective efforts made to collect, transport, dispose or recycle and efficiently monitor waste products. Whereas, waste can be defined as unwanted product, especially after the useful parts has been retrieved (Cambridge, 2019). It is however disconcerting to note that 9 out of every 10 African cities are struggling with waste disposal measures (Lyse, 2003). In Ghana, it is a common knowledge the grave state of its waste management systems such as the heaps of undisposed waste in drainage systems, overflowing disposal sites and indiscriminate disposal of refuse on its street which leads to a number of environmental issues including the reoccurring floods in the country. Improper management of waste can result in diseases transmission, floods fire hazards, odor nuisance, atmospheric and water pollution, aesthetic nuisance and economic losses (Jilani et al, 2002). Recent developments in spatial technology has however provided an integrated approach in advanced modelling to provide solutions to issues in waste management. This is to enable decision makers visualize the best approach in managing waste products such as the siting of landfills, projections in the volume of waste, efficient collection and transport routes for

disposal or recycling. GIS a tool to collect, manage, analyze and retrieve large volumes of spatial and non- spatial data and will be efficient in aiding solve issues relating to waste management. GIS also allows the user to create and store as many layers of data or maps as needed whiles providing various possibilities to integrate tremendous amounts of data and map overlays into a single output to aid in decision making (Chang et al. 1997). The study therefore seeks for amendments in the system through a GIS based model which would reduce the waste management workload to some extent and exhibit remedies for some of the waste management problems in the case study area. The GIS based application proposed by the study will solve some of the present problems including the proper allocation and relocation of waste bins, check for unsuitability and proximity convenience of waste bin to the user, proposal of recyclable waste bins for the required areas and future suggestions for environmental agencies.

In light of this, the study examined the following questions:

- To collect and organize data on waste generated within the urban area
- To monitor and assist waste collection within the urban area.
- To encourage the recycling of waste products
- To manage and create an efficient system to collect revenues from clients.

2. CURRENT TRENDS IN WASTE MANAGEMENT

Waste management is a challenge for various city authorities notably in developing countries mainly due to the massive increase in the volume of waste, the burden it poses on the national budget due to high costs associated to its management, lack of understanding over a diversity of factors that affect the different stages of waste management and the linkages necessary to ensure an efficient waste management system. The first goal of Municipal Solid Waste Management (MSWM) is to protect the health of people, particularly that of people having low-income. Secondary goals include promotion of environmental quality and sustainability and employment generation. GIS and remote sensing have not been effectively used in most developing cities. Although a few studies have been done integrating these technologies into a planning process to improve the efficiency of municipal solid waste management it remains under-utilized (Senthil et al., 2012). It is estimated that about 83% of the population dump their refuse in either authorized or unauthorized sites in their neighborhood, and due to poor handling

of solid waste, unsanitary conditions are created (Bennah et al., 1993). The common setbacks that confronted most of the developing cities were managerial and organizational inefficiencies and thus lack distribution of responsibility for different activities of waste management (Onibokum, 1999). For instance, in Ghana, a lump sum of US$67 million of its limited resources was used to dredge the Odaw river of solid waste, a major drainage system within its capital city, the Accra Metropolitan Area recently, but the issue is still predominant (Yeboah, 2019). Global records show that in 2016, the world's cities generated 2.01 billion tonnes of solid waste and it is expected to rise by 70% to 3.40 billion tonnes in 2050 (Silpa, et al, 2019). In addition, over 90% of waste especially in low income regions, are often disposed in unregulated dumps or openly burned (World Bank Group, 2019). These practices result in serious health issues and environmental degradation. While waste management is a nationwide issue in Ghana, it's most obvious in Accra, a fast-growing city of four million that generates about 3,000 metric tonnes of waste a day. In 2012, the World Bank estimated that poor sanitation was costing Ghana's economy around 420 million Ghana cedis ($290 million) each year, equivalent to 1.6% of its GDP. The study found most of these costs come from the annual premature death of 19,000 Ghanaians, largely due to poor sanitation and hygiene (Knott, 2018). Waste management is therefore one of the greatest threats facing mankind (Hoornweg, 2012) hence, proper management is essential.

Plate 1: Evidence of Poor Waste Management Within the Municipality

Municipal solid waste management is one of the major problems that city planners face all over the world. The problem is especially severe in most developing country cities where increased urbanization, poor planning and lack of adequate resources contribute to the poor state of municipal solid waste management (Obirih-Opareh & Post, 2002; Mato, 1999; Doan, 1998; Mwanthi et al., 1997). Accurate data on solid waste will enable effective monitoring, controlling existing waste systems, and also help in making regulatory, financial and institutional decisions. Unfortunately, the solid waste management system in Accra, does not have any database (Boadi, K. O., & Kuitunen, M., 2003). Much available data is based on estimates, which are in many cases unreliable. The lack of accurate data on solid waste generation and characteristics impedes any sustainable waste management programmes for the

city. This explains why the Waste Department, has often failed in the selection of appropriate technology for solid waste management. More than 3,000 tonnes of waste is produced in Ghana's capital every day, the Director of Waste Management at the Accra Metropolitan Assembly (AMA), Tony Mensah, has said. He, however, stated what frustrated the assembly's efforts mostly in the management of waste was the "bad attitude" of some citizens. Mr. Mensah disclosed that there were several people who resorted to disposing their household wastes into drains anytime it poured. He said often such rubbish blocked drains and created flooding on roads and in homes, presenting inconveniences to other dwellers in the city. The AMA, he continued, had made arrangements for the collection of refuse from residences and communities to avoid the build-up of filth across Accra. He mentioned that some waste companies had been contracted to collect rubbish from households under a five-year agreement, while the AMA had also installed communal containers in some areas where depositors paid a little fee for the rubbish they created (Bediako, 2016). The issue of waste is not only because of the increasing quantities but also largely because of an inadequate management system (E. Tinmaz & I. Demir., 2005). To manage waste data in an integrated way so that the complexity of various systems could be reduced to solve all its interrelated issues it is imperative Geographic Information System (GIS) applications are employed.

3. STUDY AREA

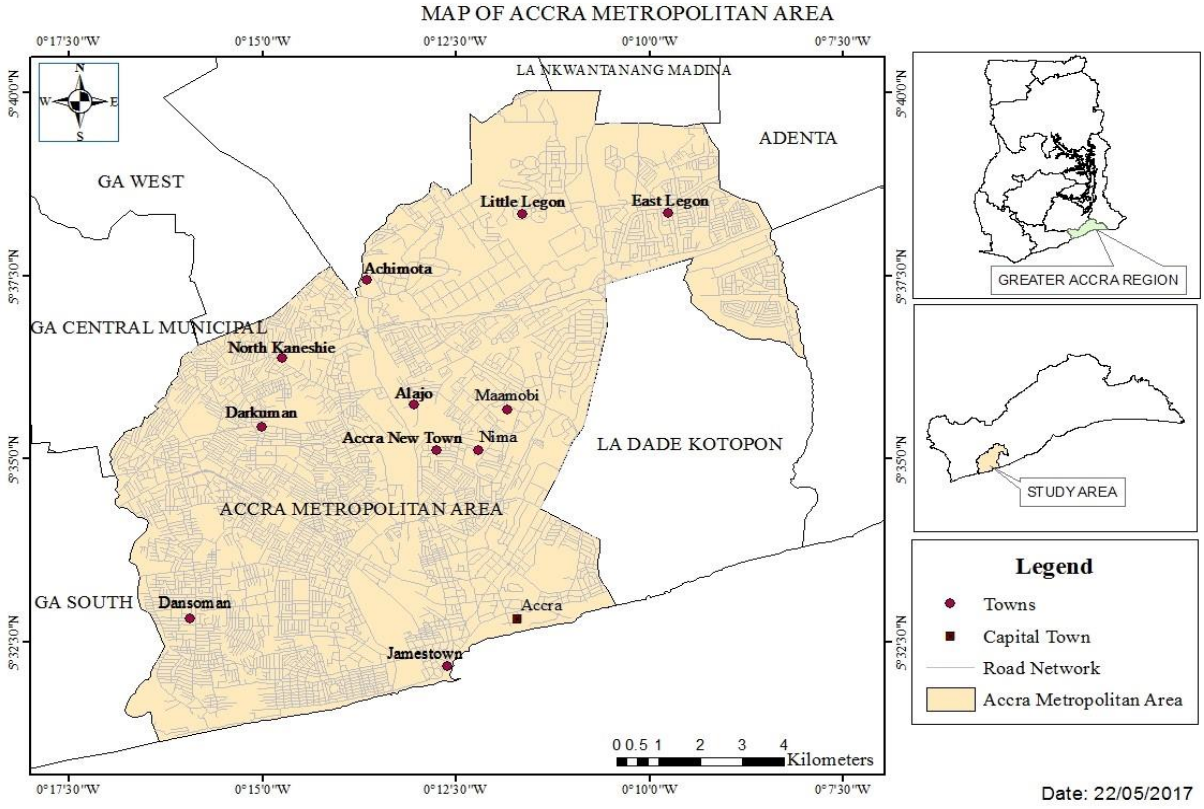

Figure 1: Map of Study Area- Accra Metropolitan Area

Accra Metropolitan Area is located between 50 33' 0" North, 00 13' 0" West in Ghana, West Africa of the equator. It covers an area of 173sq.km. The area is relatively dry since it falls within the dry coastal equatorial climatic zone. Due to its closeness to the equator, the daylight hours are practically uniform during the year with an average relative humidity of 81% (AMA, 2016). There is very little variation in temperature throughout the year. The mean monthly temperature ranges from 24.70 C in August (the coolest) to 330 C in March (the hottest) with an annual average of 26.80 C (Dickson and Benneh, 2001). The vegetation within the metropolis of Accra is mainly coastal savannah shrubs interspersed with thickets. There are a number of wetlands and water bodies which create micro-climates in some part of the metropolitan area. However, there is evidence to suggest that the original vegetation of the area has been altered in the more recent past century by climatic and human factors. Much of the metropolitan area was believed to have been covered by a dense forest of which only a few

remnant trees survive as a result of urbanization and increased industrialization. (AMA, 2016) The population of Accra Metropolitan Area according to the 2010 Population and Housing Census is 1,665, 086 representing 42% of the region's total population. The metropolis is entirely urban (100%). At the regional level, Greater Accra recorded the highest population growth rates of 3.1%. It is the most densely populated region with a density of approximately 1,236 persons per square kilometre in 2010 compared to 895.5 persons per square kilometre in 2000. The increase in population density implies more pressure on the existing social amenities, infrastructure and other resources in the country. (Ghana Statistical Service, 2014). A majority of Accra's residents live in low-income, densely populated communities, with inadequate infrastructure and services. Residents often dump their waste into open spaces, drains and rivers, which contributes to flooding in Ghana's rainy season or on open spaces. Others resort to burning it on the side of the road.

4. CONCEPTUAL FRAMEWORK

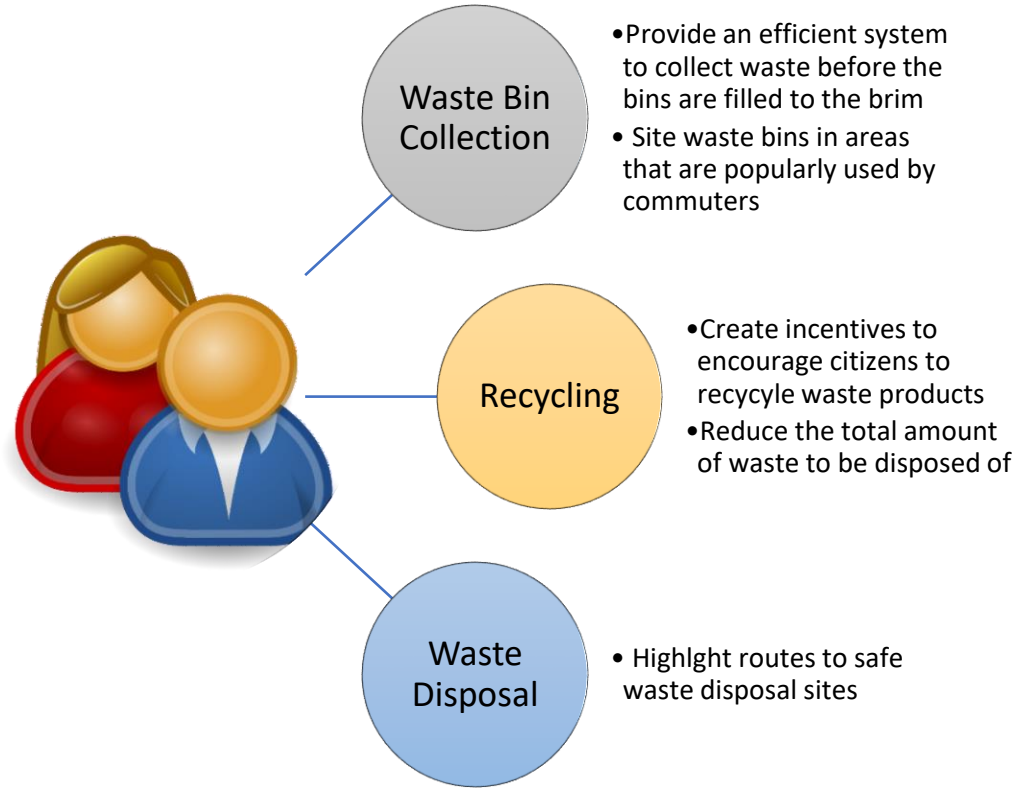

Figure 2: Conceptual Framework the GIS based application is built on

Source: Adapted from P. Singh, Y. P., A.K., S., & R.P., S. (2016)

The GIS based application focuses on three main components to ensure effective waste management techniques are adopted within the Accra Metropolitan Area. The first section is an efficient waste bin collection process. The process involves the use of waste bin trucks and waste tricycles to empty waste bins on a regular bases to prevent spillage of refuse in the municipality. The system incorporates a model for data sharing between truck drivers on real time in order to perform waste collection and dynamic route optimization. The system handles the case of ineffective waste collection in inaccessible areas within the municipality hence the use of waste bin tricycles. The second section highlights on recycling. Incentives are made by providing points to users for recycling their waste. These points are accumulated to give the use free waste bin collection services. The third section routes waste bin trucks to designated waste disposal sites.

5. RESEARCH METHODOLOGY

In order to efficiently manage waste produced in Accra, detailed spatial information is required. Hence, this was the main source of data for the research. This information is related to the geographical background of the area under investigation as well as to special data related to the waste collection procedure. In addition, interviews granted to residents within the Region of Interest and relevant scholarly articles aided to the development of the application.

5.1 Flow Chat

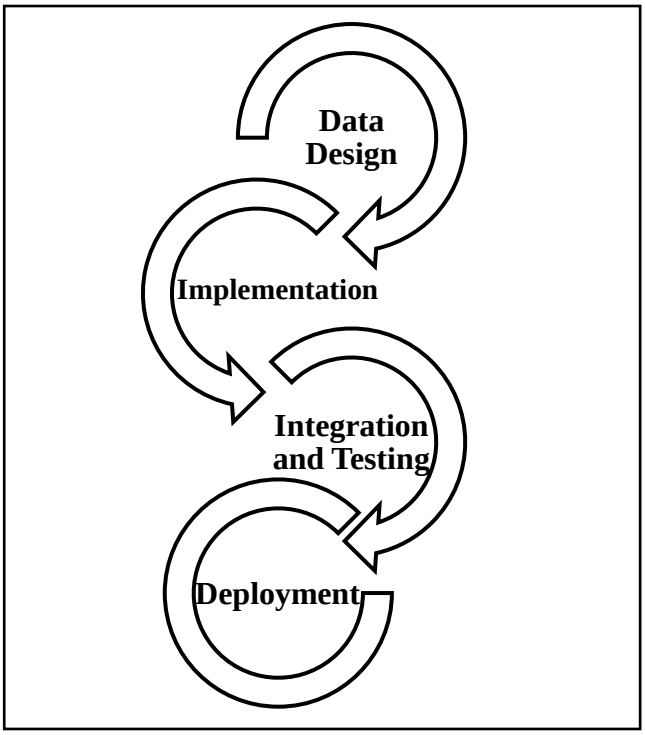

Figure 3: Flow Chat for the GIS-Based Application

From Figure 3, the structure of the data was designed and validated by specifying the appropriate data types for the schema. The schema was designed check the authenticity of the data. The design was done using a spreadsheet application and uploaded to google sheet. The software applications used to achieve the objectives of the study included; Google Sheet and AppSheet. The AppSheet environment was configured to depict the database design for the app. This was set up in AppSheet. In the creation of the new app in AppSheet, the name, title, description, version, data source was set up in the app. The data dictionary was also designed as a relationship between the data format, structure and the relationship of the various elements was established to allow appropriate access control and manipulation within the app. Furthermore, the user interface was developed to allow easy access and interactions. Views was set up on the app to allow for easy navigation within the app. The three different views, that is, form, map and data views was set up within the app. A server-side script was also developed to create and deliver notifications to the field inspector or bin management firm and bin owner

when a waste bin is cleared or changed. The App was tested on different platforms and on different locations to ensure there are no errors and the app works according specification.

6. ANALYSIS AND RESULTS

This chapter shares an in-depth information of the process undertaken in the study to achieve the objectives, the results obtained and the final outlook of the web-based application to manage waste collection within Accra has also been highlighted.

6.1 Data base design

The database was first authored using a spreadsheet application. The resulting datable was uploaded to google sheets. The data fields included:

a. **Owner ID**: The name of the owner of the asset including a unique identification number to identify each user.

b. **Bin ID**: The type of Bin supplied will have an ID, which indicates commercial or Residential.

c. **Collected Date**: The date set for bin collection.

d. Owner Contact: The telephone number of the asset owner.

e. Location: The address, place or town name where the asset is located.

f. Email: Email address if available

g. Bin Condition: The state of the Bin is in, thus, good, bad or destroyed.

h. Bin Collection Value: The estimated value of the bin collection in cedis

i. **Bin Picture:** A picture that is uploaded when the bin is first purchased or supplied. A new picture should be uploaded anytime the bin is updated or replaced.

j. **Recycle Waste:** Points allocated on recycled waste collected

k. **Inspector Name:** The name of the field personnel who collected the bin or mange the Bin

l. Date of Update: The last time the bin was disposed

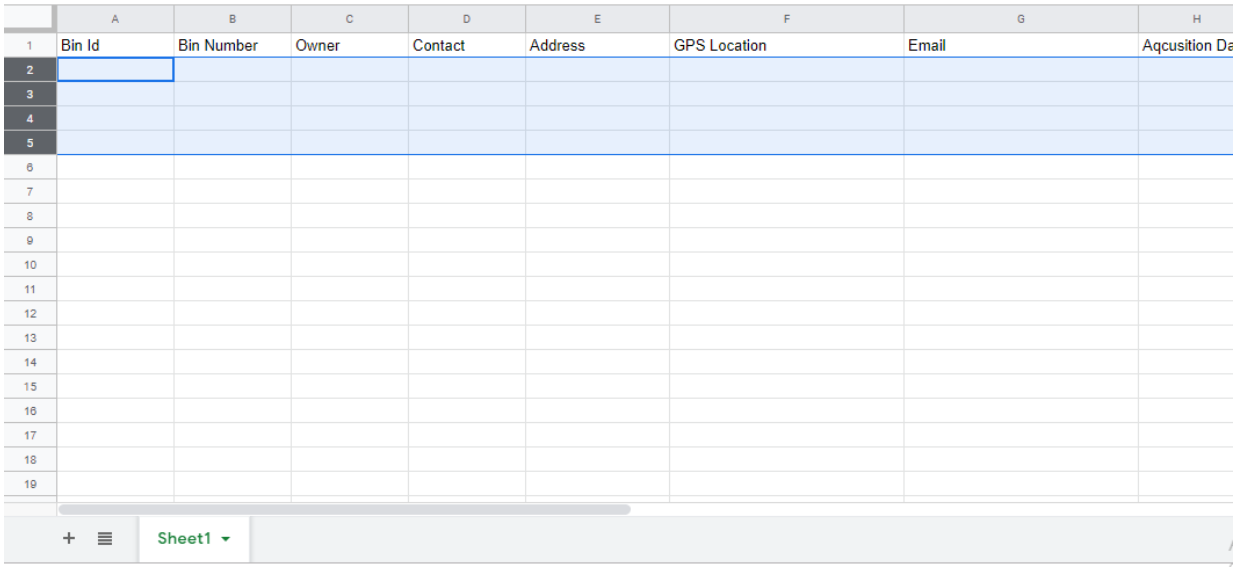

Figure 4: A spreadsheet of the database authored in google sheet

6.2 Setting up AppSheet Environment

Creating a new app in Appsheet, the necessary details and information of your app such as the name or title, description as well as the bin folder.

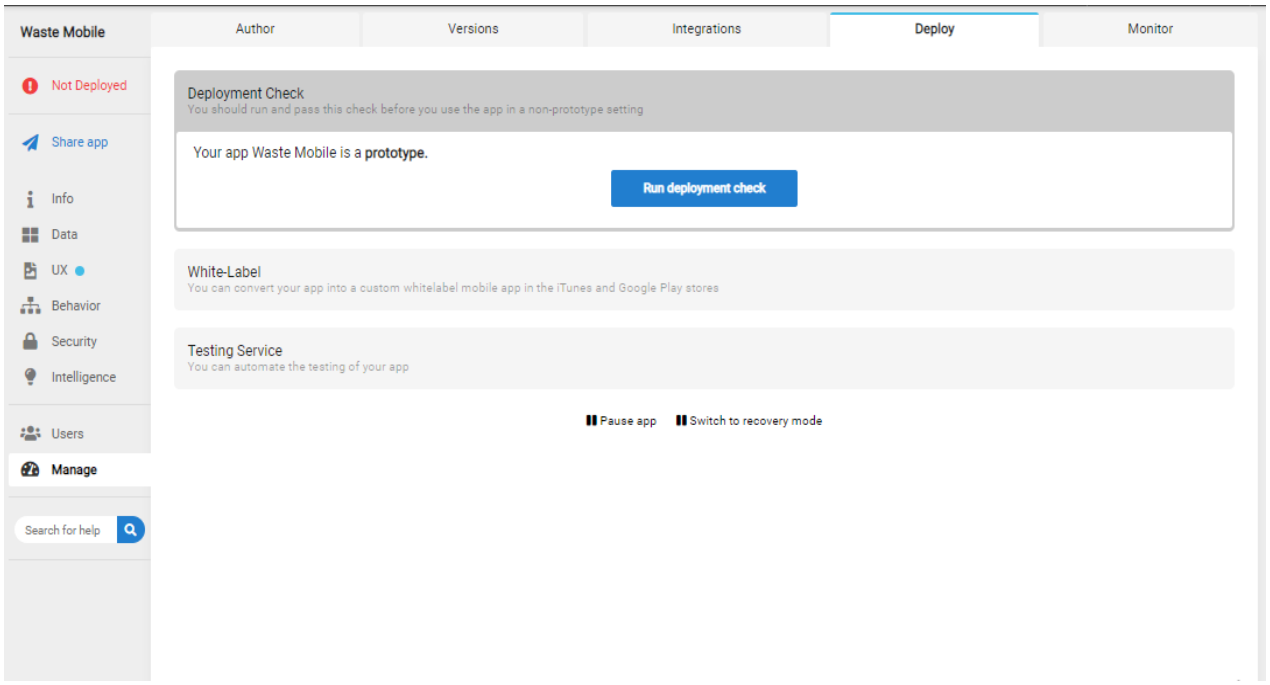

Figure 5: Bin Manager app in a Settings, non-deployed mode

6.3 Data Source Specification

To work with database in AppSheet, you will need to specify the data source of your app. In this project, google sheet was used as the data source. The google sheet was then imported into Appsheet.

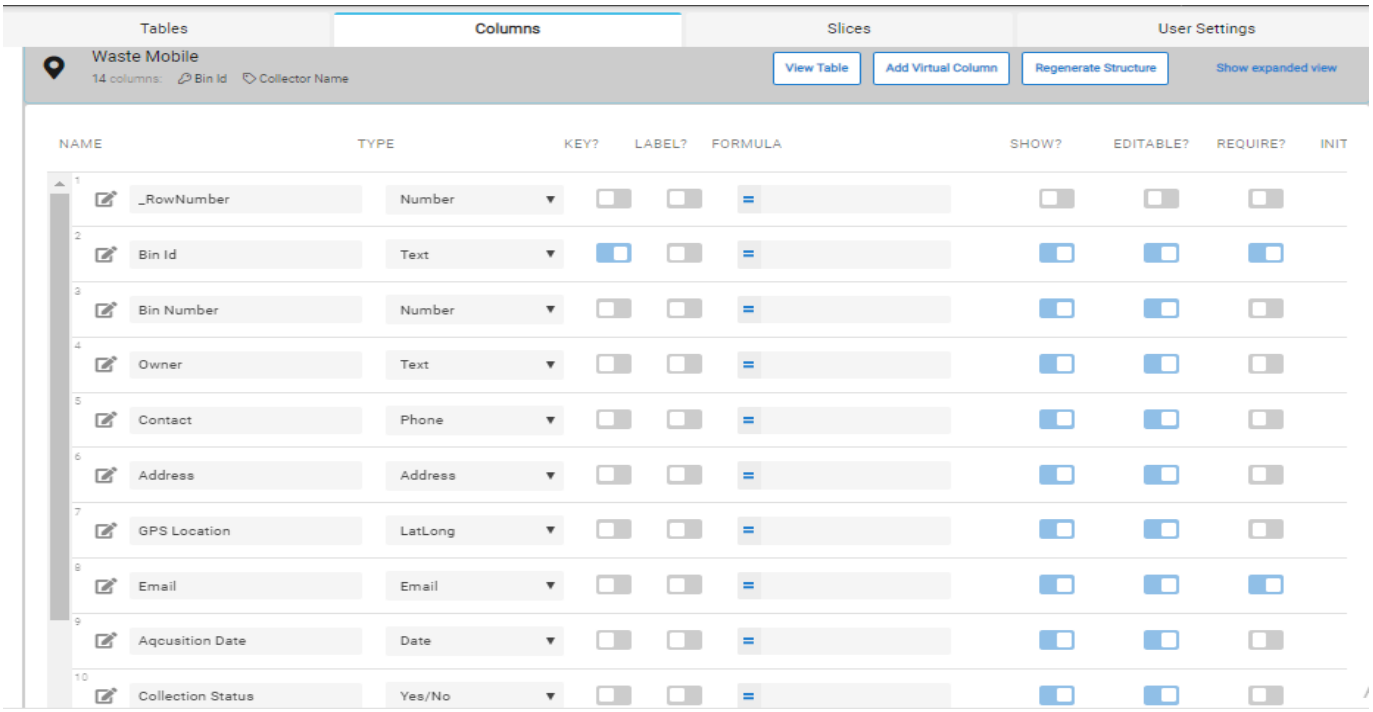

Figure 6: The database of the app opened in the Appsheet environment

6.4 Views Creation

The views allow you to set up the various navigations or menus for your app. For this app, three main views namely Form, Map and Data view were created. The views were connected and configured for the Bin database imported into the app. The Form view allows the user to add or update the database

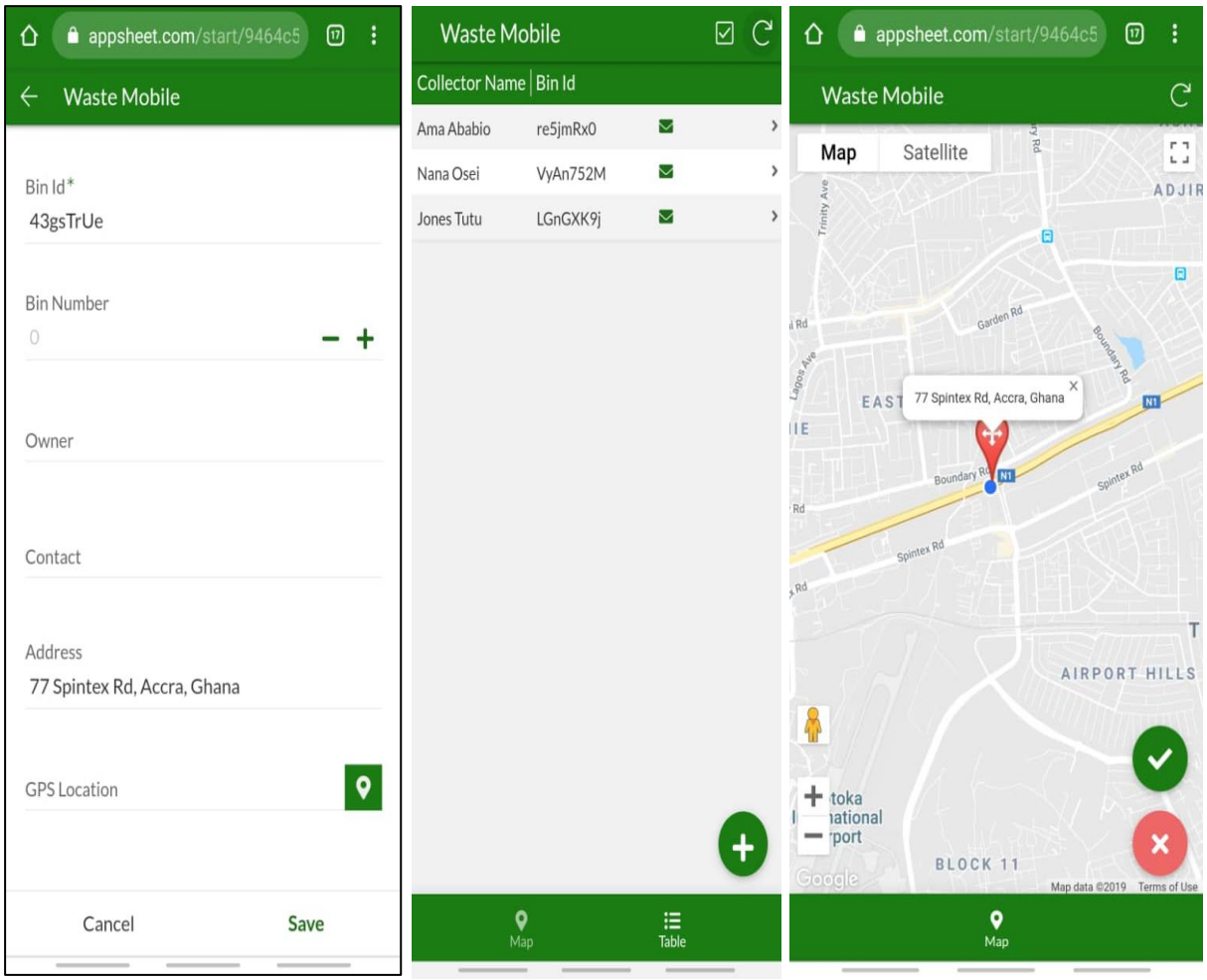

Figure 7: The App showing the Form and Data and Map View mode

The Data view allows you to view existing data in a tabular format whiles the map views allows you to view the data on a map and perform routing.

6.5 Notifications Settings

The App sends notification to both the field Personal and the Bin owner anytime an any update is created or updated. The bin owner receives the notification through his email account for the respective asset. The proposed application will enable both the field inspector or Bin management companies and Bin owners to track information concerning Bin collections.

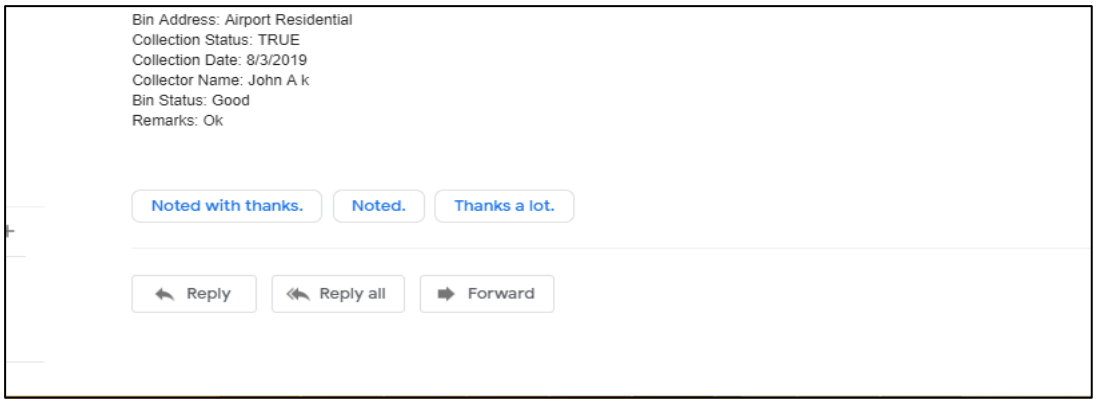

Figure 8: A sample of an email sent by the app after a Bin collection was update

6.6 Navigation Settings

The application allows users or field inspectors to navigate to the location of an asset. This implies that different field inspectors can visit or navigate to the same asset without worrying so much about finding their directions. Routing or navigation is made possible with the help of the Google Navigation.

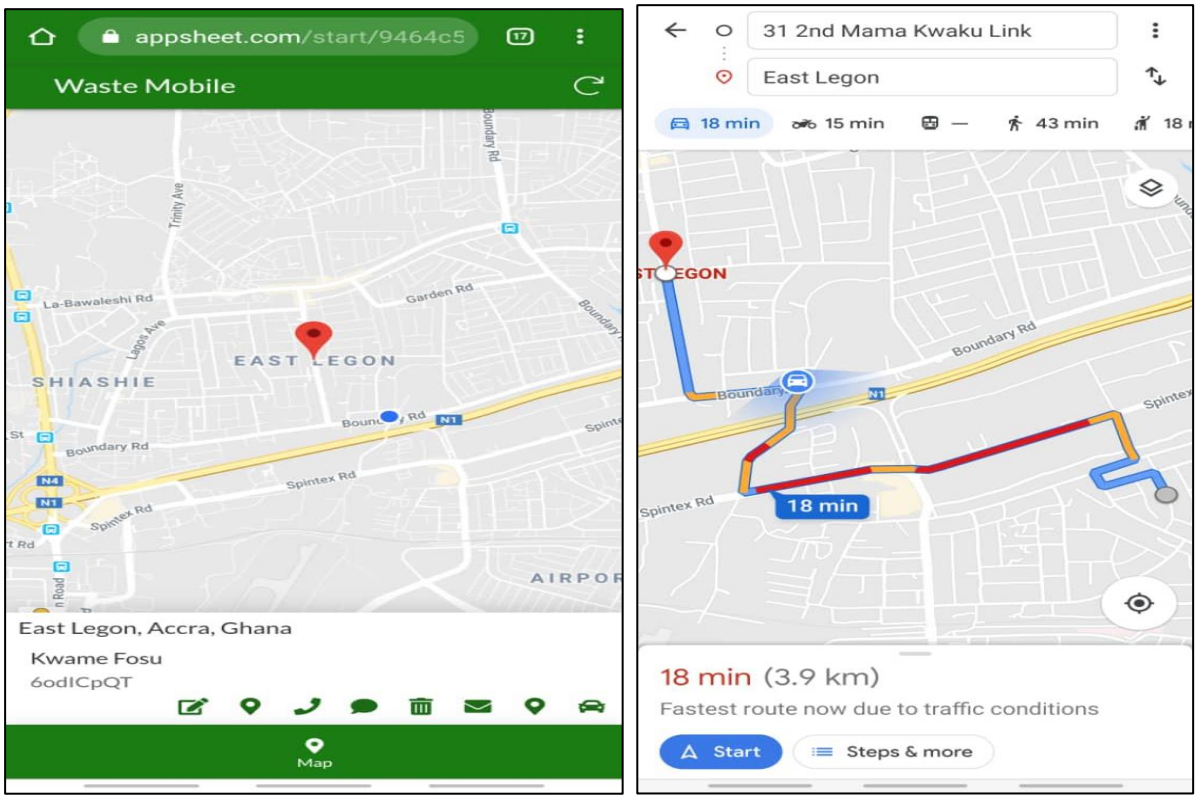

Figure 9: Web App displaying the routing tool which shows waste bin collector to bin location

7. CONCLUSION

The study has demonstrated the use of geospatial tools as the best method to manage waste bins in Accra. A GIS based application to manage waste was successfully developed. This has created an opportunity for the users to have an efficient way to keep track of waste collected, collate points when they recycle and also pay their waste collection bills. This study if adopted will greatly solve issues relating to the proper disposal of waste, its management and supervision. In addition, periodic reviewing, accessing and updating spatial and attribute data of the bins related to their storage capacity, collection frequency and transportation is required to be maintained to evaluate waste management practices from to time. The GIS generated reports can also be utilized by the municipality to record the status of the bins (cleared/uncleared), number of trips made in a day, attendance of sanitary workers, quantity of waste deposited at the transfer station, etc. on a real-time basis for decision making by relevant stakeholders.

8. RECOMMENDATION

- Educating children and making recycling and reuse compulsory in all organizations should be key aspects in reducing the waste generated in the cities daily.
- Extensive public awareness should be made on how GIS technologies can improve upon waste disposal methods within the country. This will help make our cities neater.
- Seminars should be held with the Municipal officers and the stakeholders involved in the solid waste management to educate them on managing the cities effectively with the help of GIS system. These maps will help officers to identify and monitor the waste generated to be able to make more informed decisions on policies.
- Promoting waste markets and recycling companies through tax exclusive incentives would help to reduce the total volume of waste at the landfills.
- The government should invest resources in geospatial tools for waste management in Ghana. This is because there is a need to improve the data system of solid waste for the monitoring and management to ensure environmental sustainability.

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BIOGRAPHICAL NOTES

Stephen Djaba is the Chief Executive Officer at Geo-Tech Surveys Ltd, a Licensed Surveyor in Ghana involved on various planning and evaluation committees. He is a staunch member of FIG since 1994.

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