E-Tracking System for Solid Waste Management Using RFID

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ABSTRACT

The Radio-Frequency-Identification (RFID) technology uses wireless radio communication to identify and trail tagged objects without any form of a direct link. Today, the RFID technology has increasingly been adopted in many industries and is regarded as one of the significant factors in making work easier and efficient. RFID application is increasing rapidly with the potentiality to label any item with an affordable communications chip and then read that label with a reader. Endless applications of this technology range from asset tracking to security tracking to supply chain management. The increase in business operations of all forms in different sectors has led to challenges in solid waste management. To show some of the potential applications of RFID technology in the modern society, this paper explores the use of an e-tracking system in solid waste management using RFID technology. The paper then gives an overview of the technology's critical features which give it popularity in waste management and other fields. Application examples of RFID technology in waste management are also given. It is hoped that this report will provide valuable information to researchers in technological applications such as RFID, and that it can be used as a guideline for future research.

Keywords: *Radio frequency identification, electronic monitoring, waste management, e-tracking*

1. INTRODUCTION

Urbanization- "the proportional change between the population living in rural areas and that in urban areas" is one of the most evident changes worldwide today. African countries such as Kenya are at an accelerating stage of urbanization. In the last ten years, the population has grown rapidly and the number is expected to increase [1]. Rapid growth in urban population leads to a dramatic increase in municipal solid waste (excluding industrial, construction, hospital waste) with severe social economic and environmental impact.

Therefore, there is an inescapable need to manage municipal solid waste in a proper way to create a safe environment for plants and animals. Information technology has well equipped this sector for the efficient functioning of its mandatory functions [13]. In this paper, an attempt is made to propose an automated solid waste collection monitoring system using RFID technology with the global positioning system (GPS), the geographical information system (GIS), and the global system for mobile communications (GSM).

RFID is a generic term for technologies that use radio waves to identify people, animals or objects without being in physical or visual contact with them.

The proposed system consists of RFID tags mounted on containers, RFID readers mounted on trucks along with GPS for location tracking and GSM module for wireless transmission. The system provides real-time monitoring of waste collection through a web based application. This application helps administrators in decision making related to reallocation of routes and containers and handling management issues such as observing performance of contractors and waste generation characteristics of a particular area. It also enhances transparency in the working of the civic administration [8]. Real-time information collected via RFID and GPS transmitted via GSM provides added value in services like Usage and route planning optimization of garbage trucks, efficient monitoring, and management of waste bins and verification of collection service, as well as better recycling [1]. The aim of this paper is to offer insights on how RFID technology is useful in solid waste management. For better and easy management of waste, it is advisable to come up with proper ways of disposing solid waste from the start rather than doing it later, when the solid waste has accumulated hence more difficult to manage.

2. LITERATURE REVIEW

The Radio Frequency Identification (RFID) technology is the wireless application of electromagnetic fields to channel data for automatically identifying and trailing tags attached to objects without any direct view or contact. It is made up of three components: the RFID tags or labels, a computer system and the RFID readers also known as interrogators [8]. The RFID technology takes the bar coding construct and computerises it to offer unique potential to carry out interconnected operations.

Some of those operations involve uniquely identifying a specific item beyond just its product type, and to recognise items in the absence of a direct view or line-of-sight [6]. Also, RFID enables easy recognition of several items simultaneously and identification of items within a given locality of between a few centimetres to several metres. Notably different from a barcode, the RFID tag does not have to be within line of sight of the reader to work well, it can be implanted in the tracked object and still work [9].

The RFID tags or labels [7] comprise of a microchip and an antenna, whereby the tag is attached on, printed on or added to a product, person or animal to provide a distinctive identifier. On the other hand, the RFID readers or interrogators are made up of an electronic card and an antenna. When connected, the RFID tags convey information to one or several RFID

readers through a radio channel. This transmission is made on different frequencies, with the RFID reader requiring a computer code or signal to transmit information. A dialogue is created based on the set communication protocol. The computer system is critical to the RFID technology, whereby the reader changes the data conveyed by the RFID tags into digital data and channels it to a computer. The computer system stores the data or seeks information on the tag identification number in a database to command further action. The reader and the computer are interlinked by cables or radio. RFID is an upcoming technology with the potential for improving operations in the retail, manufacturing and service sectors [8]. According to market research done on the RFID technology, the cumulative sales of RFID tags have been going up in the past few years. By the year 2014, the global RFID market was worth more than 8 billion dollars. This figure includes the value of software, tags, cards, fobs and readers, as well as all other form factors. The market value is likely to rise significantly by 2020 [9].

Solid waste comprises of a collection of the hazardous and non-hazardous unwanted substances disposed off by different institutions, homes, industries, markets and even streets. These substances in one way or the other pose different dangers to the environment when not properly managed. In developing nations such as Kenya, waste management is an issue of concern especially because of lack of monitoring and proper disposal of waste. For instance, a fairly large part of solid waste generated in Kenyan counties is not handled according to the stipulated environmental management standards. The norm is that such waste is either burned openly in the streets or is left in the open land and in some cases discharged to water catchment areas. Where there are attempts to manage solid waste the approach is such that - trucks are sent to the waste collection centres to collect the solid waste. The waste is loaded into trucks and then ferried to the predetermined locations.

Unfortunately, the personnel involved in the collection and ferrying of the wastes are usually not responsible enough to carry out these tasks efficaciously.

In most situations, the waste is not collected from each and every waste collection centre as expected because of the bad attitude of some of the personnel. This has contributed to innumerable issues such as the absence of information on the collection time and area, lack of proper checking system and lack of follow-up on the status of the waste collection centres [12]. The waste collection or cleaning activities in Ngong town are carried out by two departments: The first one is the environment conservancy department that is in charge of street sweeping, cleaning of public areas and dumping areas, as well as the estate to estate collection of garbage. The second is the solid waste management department that is in charge of collection, transportation, processing, storage and disposal of the town's solid waste. To enable the two

departments carry out their functions well, each urban area in Kajiado County has designated waste collection points, communal bins, vehicles and personnel. In the case of Ngong town, it has more than 100 waste collection points and more than 50 communal bins, 20 mechanised vehicles are deployed for transportation and more than 200 personnel to execute assigned duties [3].

Why apply RFID in waste management? RFID technology has the potential to both greatly make better and protect the lives of members of the public, and change the way public organisations such as counties carry out their operations. As the most flexible auto-identification technology, RFID can be applied to track the physical world mechanically or automatically and with precision. RFID can indicate what an object is, where it is, and even its state, which is why it is inherent to the development of a tracking system – interconnected web of objects; automatically sensing what is taking place, sharing related data, and responding [8]. RFID application is increasing rapidly with the potentiality to label any item with an affordable communications chip and then read that label with a reader. Endless applications of this technology range from asset tracking to security tracking to supply chain management. Whatever the use, RFID has the capability to improve the efficiency of operations, better asset visibility and traceability, reduce dependence on manual processes, cut down operations costs, and provide critical information for decision-making [9].
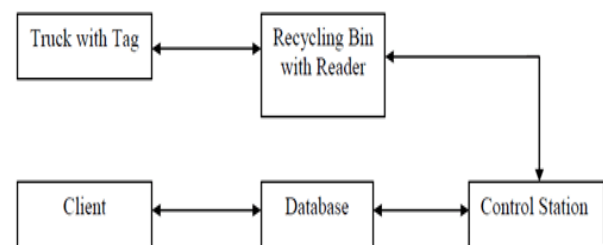

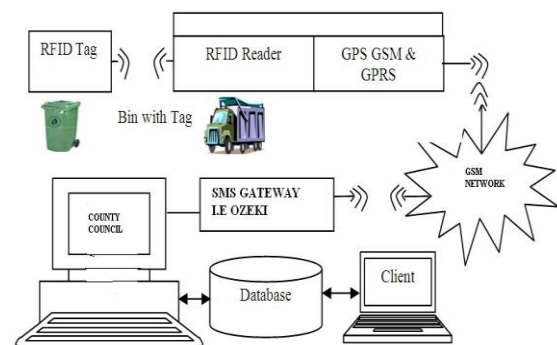**Figure 1:** Block diagram of the system

Figure 2: Architecture of the RFID system

Since the start of urbanisation, urban centres have focused on offering better services among them waste management. Solid waste management in developed nations is a major concern considering the slow response by the concerned authorities to dispose or recycle waste. On the other hand, the public in the developing nations like Kenya are demanding for proper solid waste management to ensure a safe environment.

For a town such as Ngong in Kajiado County that has a high population and is developing at a fast rate, proper solid waste management is unavoidable.

Timely and effective management of solid waste at a reasonable cost is a priority for nations that care for the welfare of its people [3]. Though the RFID technology has turned out [9] a key factor in electronic tracking of solid waste and its management, most counties in Kenya have not taken advantage of this technology leading to ongoing issues of solid waste management.

3. RESEARCH METHODOLOGY

The paper explores an e-tracking system using RFID technology for solid waste management, taking a case of Kajiado County, focusing on Ngong Town.

Primary along with secondary data was used to respond to the research question. The research questionnaire had both open-ended and close-ended questions covering a range of aspects of the research topic. The questionnaire was chosen over many other data collection instruments because it guarantees a high response rate [2], and it needs less time as well as energy to distribute and collect data. The questionnaire also offers fewer avenues for prejudice, since the information is submitted in a coherent way [4]. Secondary data was collected from published books, journals and online journals on the research subject [5]. In this report, data was analyzed by locating and gathering research documents, focusing on the research variables. Data from the questionnaires was analyzed using the spreadsheet program – Microsoft Excel. The collected primary and secondary data was then integrated. The advantage of integrating the two is that it leads to data triangulation, whereby data or findings are authenticated. Doing so increases dependability and backs the research findings [10]

4. RESULTS AND DISCUSSION

The research question was to explore how an e-tracking system using RFID technology can be used solid waste management. Both the literature reviewed and the primary data findings gave an elaborate response to the research subject - e-tracking system for solid waste management. Notably, in the waste industry, an increasing application of wireless technology is in the use of RFID tags. Waste bins are installed with microchips to enable scanning by the waste collection vehicles, whereby such tags link the waste bins to the respective

households. The vehicle is equally installed with technology that checks and weighs the contents of the waste bin of every household. These data is documented on an onboard information system to establish each household's waste [13].

As mentioned in the methodology, the chosen sample is Kajiado County, specifically Ngong town. This county was chosen because of its long-standing efforts to solid waste management, and the extent of public concern for keeping the environment safe. Also, Ngong town is the second most populated town in Kajiado County, making waste management an inescapable task. From primary data collected, it indicated that the county's top management claim that extensive efforts are in place to keep the environment safe. However, the residents disagree arguing more must be done in solid waste management. The efficiency of solid waste management systems is dependent upon systems adopted in the entire process. There is plenty of room for improvement for Kajiado County in solid waste management using the RFID technology. However, it is important to get practical on the adoption of the technology. The fundamental principles of wireless technology are well-known; however, feasible application to the waste industry in Ngong Town is still relatively new. Weighing waste bins at the same time as they are emptied is yet to be adopted in Ngong town, but shows promise for future adoption. This promise is in cost reduction, improved efficiency and recycling rates [3]. On the basis of the above summary of the research findings for the research question, it is evident that the research question is answered.

As earlier mentioned, the research questionnaire was distributed to the county employees via electronic mail to the human resource director who then distributed to employees in the Environment and Natural Resources Ministry of Kajiado County, focusing on Ngong town. Participation of employees was strictly voluntary. 50 questionnaires were filled as requested since 50 had been calculated as an ideal sample size. A period of three weeks was set for the completion of the questionnaires and their return. At the end of the three-week period, 50 questionnaires were returned. The results of the questionnaires are presented below in a comparative format.
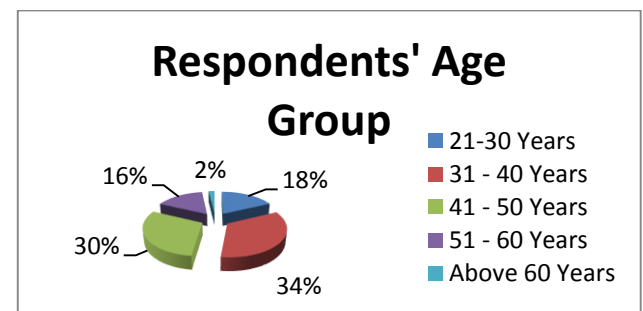

Figure 3: Respondents' age group

Demographics

Respondents' age group

According to Figure 3, 18% of the respondents were in the 21 – 30 years category, 34% were in the 31 – 40 Years category, 30% were in the 41 – 50 Years category, 16% were in the 51-60 Years and 2% were above 60 years. This analysis shows diversity in maturity of participants that accounts for their different viewpoints in their responses to the questionnaire. Also, this is an indicator that all the respondents were adults, who consented to willingly take part in this study.
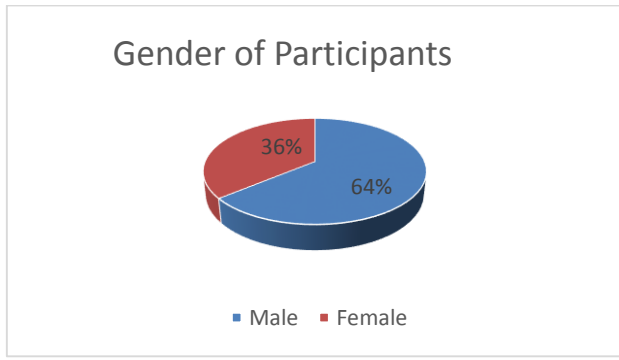
Figure 4: Gender of participants

According to figure 4, 64 % of the respondents were male and 36% were female. This means that the dominant gender among respondents is male. Different genders have divergent views on the issues of technology and its application in waste management, that were considered in this study.

Education Background
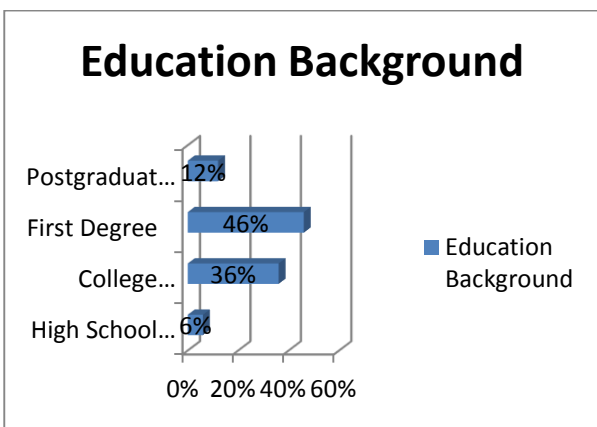
Figure 5: Education background

The respondents were requested to indicate their education background and the findings indicate that more than 50% of them had additional education qualifications besides their High School or secondary school certificate.
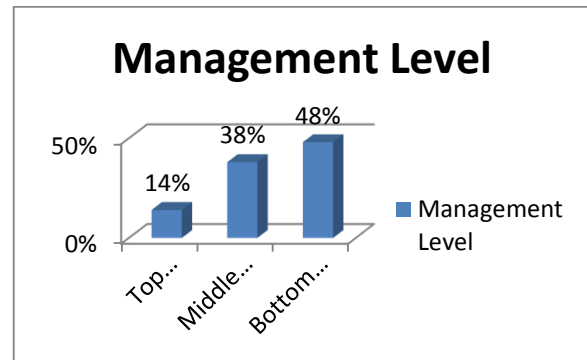
This shows that the respondents were knowledgeable enough to understand and respond to the research questions.

Years of work experience

The figure below shows the years respondents have worked with the current employer. 32% had worked there for 0 - 5 years, 38% for 5 – 10 years, 24% for 10 – 15 years and 6% for more than 15 years. This indicates that majority of the respondents were experienced enough in their jobs to understand whether an e-tracking system can be used in effectively managing solid waste using the RFID technology.
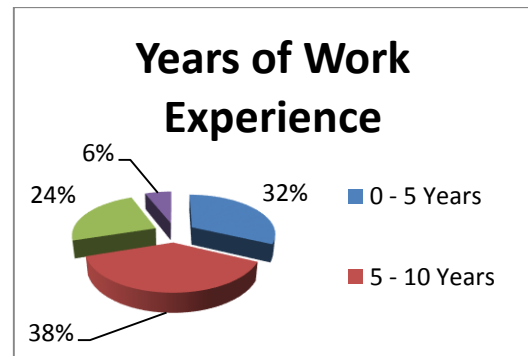
Figure 6: Year of work experience

Figure 7: Management level

Of all the respondents, 14% were from the top management level, 38% from middle management level and 48% from bottom management level. This shows that there was a fair representation of all management level and different viewpoints concerning the research topic.

The RFID technology

The questionnaire findings along with reviewed literature indicated that nowadays, RFID systems are commercially available for different applications such as transportation and control access among many others.

However, RFID tags along with sensors association offer several new solutions to develop and manage notably environmental friendly undertakings such as more efficient waste management and many other

environmental challenges [6]. This paper is on the use of RFID technology in waste management. The study established that Kajiado County applies the RFID technology in its solid waste management activities; however, its use is on a testing level. This system has not been fully embraced. The county estimates that waste collection in Ngong town costs Ksh. 1200 per kilometre including fuel, labour and other related costs. Whereas this system is under trial in Ngong town, initial results look very encouraging. Where the system has been used in Ngong town, results indicate increasing efficiency in managing solid waste [3].

Information technology is turning out as crucial in the waste collection as it is elsewhere. Establishing when a bin ought to be emptied is useful information for a waste collection authority. When equipped with this information, the concerned authority can visit the waste collection centres when the containers on that centre are full, hence cutting down the frequency of needless journeys and securing cost savings in work time, fuel and other related costs. Moreover, data gathering systems seem set to play a critical role in tracking the performance of variable charging as well as recycling schemes. Still these technologies can only optimise their positive effect if they are implemented as part of a well-structured waste collecting and recycling system [1].

Collecting data from personal interactions with the residents in an area offers crucial insight into residential recycling habits. Advanced computer systems offer the technological support that makes the manual work pay off. The results from this study highlight the gaps on how much residents / county staff believe they are recycling and their actual output. Where there is a gap, interlinked communication campaigns can be applied to more extensively engage residents or staff and change their habits. Those communications can be sent via social media, mass media or short messages through mobile phones [7].

Designing waste bins to output data themselves is one way to match up information in an optimal manner.

With this technology, each waste bin is fitted with a sensor and remote messaging system that relays information or short message to the waste management department when nearly full. Each message updates the concerned authority and allows for regular checking and saving on manpower and other related costs. A GPS system grades and at the same time informs the office of the collection urgency of the disposed waste. This awareness system is critical in reducing cases of waste overflow and leads to the smooth operation of solid waste management initiatives. On the other hand, waste bin tagging accompanied with data collection can shed light on individual household waste disposal behaviours [6].

Waste management and RFID technology
With costs going up in the waste management process, RFID is enabling counties, cities and even municipalities to carefully identify individual waste disposal containers and can create dependable waste recycling programs that reliably minimize the amount of trash. By automating the collection of all solid waste, RFID technology can assure that individual waste baskets have been collected, providing verification of service.

Moreover, this information can be utilized to maximize truck usage as well as routes. Processes can be simplified and made more accurate [8]. Reviewed literature indicates that use of e-tracking in solid waste management through use of RFID technology helps a lot to improve efficiency of waste management operations.

To get there, a well-structured rugged RFID tag is fixed on the waste bins. It has all the owner or user information. An RFID reader or antenna installed into the truck captures the tag identification details of each waste container. The data collected from the RFID tags is matched with a time stamp, type of waste container, and its weight, and user information. The collected data is either sent to a host computer using wireless protocols or it is kept in the truck on board computer and later moved to a central waste management system for data processing [9].

5. CONCLUSION

The aim of this paper was to explore an e-tracking system using RFID technology for the proper management of solid waste, in efforts to create a green environment. The RFID technology is the wireless application of electromagnetic fields to channel data for automatically identifying and trailing tags attached to objects without any direct view or contact. In doing so, it helps those responsible to plan and coordinate planned activities as expected to realize desired results. It is a technology that is promising and recommended for use in different fields among them waste management, to provide viable solutions for creating sustainable environmental management solutions. County governments in Kenya such as Kajiado can utilize the RFID technology and track the waste collection, disposal, and recycling activities in real-time. Also, based on the documented information they can generate regular reports and evaluate workers' performance and rectify areas that need attention to improve their productivity. Moreover, collecting data in this helps to streamline management of solid waste, and hence encourage better waste handling and treatment. The findings of the primary along with the secondary data provided responses for the research question.

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