Application of Mobile Technology in Waste Collection

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Abstract

One of the stages in waste management is waste collection, and as global waste generation continue to increase year after year, the need for better and more efficient waste disposal, collection and management methods become more evident and urgent. Automated forms of waste collection are very expensive and far from being affordable in many low income communities, especially in the so called developing countries. To solve this dilemma, mobile technologies are considered for use in waste collection as a prospective means of improving waste management.
This paper is an attempt to proffer a generic but yet concrete and efficient solution to the problems associated with waste collection via the application of mobile technologies, firstly, by tackling the problems individually in form of subsystems and then, through integration of the subsystems together.

Keywords: Mobile Technology, Waste Collection, Waste Management, RFID, Tracking.

1. INTRODUCTION

One of the problems that have plagued mankind for a long time is improper waste disposal. Despite many initiatives taken to resolve the problems associated with wastes, waste generation and accumulation has continued to increase yearly.

Municipal Solid Waste (MSW), garbage as it is known in the US or refuse as it is called in the UK, which comprises of all sorts of discarded 'everyday' items like left-over food, containers, papers, faulty and unrepairable electronic appliances from households, institutions and industrial sources. In the US alone, there is documented record of unprecedented waste disposal and accumulation in the last half decade, and this is attributed partly to increase in population and waste per capita generation [1, 2].

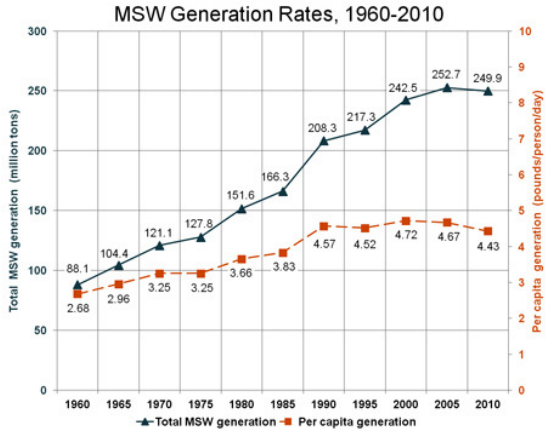

FIGURE 1: MSW Generation Rates, 1960-2010 (Source: Environmental Protection Agency).

The growth rate of waste in China over the last 20 years has exceeded that of other nations, in fact it is projected that China would produce twice as much waste as the USA by 2030, with over 1.5 billion tons of waste generated in urban areas alone yearly [3, 4]. The situation in the UK and EU is not any different too [5].

To reduce the effect of waste production on the environment, health, and quality of life (as they are all interconnected), different forms of waste management are being proposed.

1.1 Definition of Waste Management

As defined in the 'Waste framework Directive 75/442/EEC', "Waste management is the collection, transportation, recovering and disposal of waste along with the supervision of such operations and after-care of the disposal sites," [6].

Although definitions of waste management and the management practices may differ between rural and urban areas, residual and industrial regions, as well as between the so called developing and developed countries, they all include the component of waste collection which is an important part of the management process [7].

Waste collection is the premier phase of waste management, involving the collection and transferring or transporting of waste from the site of generation to the treatment or disposal area. Typically during waste collection, the waste is usually put in the allocated container or bin on the collection day, then the waste workers move from house to house collecting the waste bins and emptying them into their waste collection vehicle or dustcart.

1.2 Waste Collection Problems

The traditional waste collection method had always been sufficient for collecting waste, but with continuous increase in the amount of waste generated and the number of people needing waste collection services this method has lost its efficiency and become rather tedious to manage. Some of the areas where problems have been encountered include report filling, clients and billing management, route scheduling and uncollected waste (possibly because the waste was not ready at the collection time or probably because it was unpicked by the waste workers). These problems and others have inspired other means of collection, such as Automated Vacuum Collection System or Pneumatic Refuse Collection System.

Although the automated vacuum collection system is fully automated, requires less manpower, provides more favorable working condition for the refuse workers and is faster, it requires a very huge capital to procure, install and maintain [8], leaving it out of option for most resource-limited countries, small regions or areas and old communities.

2. OPPORTUNITY

With the almost unaffordable high cost associated with the Pneumatic Refuse Collection System, many communities are unwilling to or just cannot afford to adopt such system, thus, leaving only the option of adapting the traditional method of collection or upgrading it to meet up to the current challenges affecting it.

The present waste-associated situation has led to the application of IT and mobile technologies to help solve some of the problems affecting typical waste management. An example of such applications is 'Fleetlink' which is an in-vehicle telemetry-based product used for tracking refuse trucks [9, 10]. Another example is 'Recycle T' from a town in Madrid. The 'Recycle T' is a mobile technology solution developed by Everis and Orange to solve waste management and collection problems using Near Field Communication (NFC) [11].

Harrow, a Borough in Northwest London also uses mobile technologies in the form of mobile computers with fleet management and route optimization software to improve waste collection services.

3. PROPOSED APPROACH

Looking at the vast number of mobile technologies available, the speed of development and the convenience their application is bringing to many different fields, coupled with the success reports of several solved refuse management problems, the world of possibility and prospective efficacy of the mobile technology will be further explored. This is intended to be achieved in this paper by starting with a comparative analysis of their strengths and weaknesses and concluded by providing a generic solution to waste collection.

The proposed approach entails creating subsystems, with each subsystem solving a particular business process area for each subsystem, the available mobile choices shall be listed out and compared against each other to choose the best suited option, then the subsystems shall be integrated together to present the general waste collection solution.

4. MOBILE TECHNOLOGY

Also referred to as mobile communication technology, mobile technology includes various types of technologies such as GSM, GPRS, wireless LAN, satellite communications and devices such as cellular phones, Global Positioning Systems (GPS), Bluetooth and the list is endless.

When mobile technology is mention, one term that instantly comes to mind is wireless technology. For a system to be mobile, it most probably must be wireless, but wireless systems are not necessarily mobile. For example, a cellular phone (mobile) can handover between different networks when connection is weak (roaming), but the cordless phone (wireless) has to be within a stipulated coverage area to operate. Cordless phones usually are fixed phone with fixed area/region codes, but without the connecting wire, thus offering some restricted form of mobility [12].

In this paper, mobile and wireless technologies shall be used together as part of the subsystems to provide the final integrated system solution to the waste collection problem.

5. SYSTEM DESIGN APPROACH

5.1 Dustcart Tracking/ Fleet Management

A couple of methods can be used in tracking or attaining the positioning of a vehicle (dustcart in our case). Possible methods include satellite tracking system, mobile or cellular based tracking system and Radio Frequency Identification (RFID) tracking system.

5.1.1 Cellular Tracking System: Cellular tracking systems work using triangulation calculation based on Cell of Origin, Time of Arrival method among many criteria, and can be used to track dustcarts, but the accuracy it offers is low (hundreds of meters), which makes it unsuitable for use in this subsystem.

5.1.2 RFID Tracking System: With RFIDs, it is possible to create a tracking system for the dustcarts. To accomplish this, RFID tags can be installed at specific distance from one another, for example, every 200 meters while the dustcart has a reader installed on it. Every time the dustcart passes by the tags, the reader picks up the signal codes and sends it to the monitoring system at the central office. To know where a vehicle is, the last code sent in is checked against the database which contains the position detail of each tag.

Some of the advantages of this method include, that it can be created cheaply; and it is also easy to track the nearest dustcart to a particular location (for redeploying). The disadvantages of this system however is the difficulty of maintenance and the a requirement that tags must be within

the range where they can be read by the scanner on the passing dustcart, it is also possible for the scanner to pick up and send unnecessary codes from other similar tags within range creating error in the database. Another limitation of this system is that of the accuracy of location provided, which is dependent on the amount of tags used and the distance between two tags. The shorter the distance between the tags, the higher the accuracy provided but the more the amount of tags needed. Also to make this system user friendly, good graphical management software would have to be developed.

5.1.3 GPS Tracking System: Tracking system based on GPS can be used in knowing the position of a dustcart at all time. To achieve this, a GPS tracking device is installed on the dustcart, and the information about its location made available to the central office. To transfer this information, it is possible to use satellite transfer method or to transfer through a mobile network. For this subsystem, the mobile network transfer method shall be used because it is less expensive than the satellite transfer method, and mobile network is readily available, without need for installing any expensive components or dealing with complex maintenance problems [13].

5.2 Route Designing

This subsystem is depends on the subsystem above, and as such can be best accomplished together with it. From the tracking systems discussed; based on the information gathered, some parameters can be obtained about the vehicle such as speed, direction and location. With this information, the duration it is going to take the dustcart to arrive at a particular location can be predicted. To be able to make accurate predictions, the parameters need to be fed real-time to a management system (software) that makes calculation (prediction) based on them. This requirement of real-time feeding of parameters and the lack of direction (heading) which is a major parameter for the calculation makes the RFID not a very suitable solution for the two subsystems, so the GPS tracking system shall be used along with graphical software. To design routes, earlier routes pattern can be stored in a database and used to identify area that continually encounter problem which should be avoided when designing and optimizing new routes.

5.3 Communication

As it is sometimes necessary for the dustcart drivers to be contacted for redeployment to some other location for other pickups, a means of communication is needed.

Possible options for such subsystem are Voice (GSM, Satellite) and Data (GPRS, Satellite). Considering driving rules and safety, and the fact that detailed information which should be jotted down might need to be passed across, the voice option is eliminated.

For message or data communication, the pager, GPRS or satellite devices can be used, but since the pager is a one way communication device and cannot allow the drivers to communicate back with the central office to accept or decline new tasks, it is not seen as a suitable option. Comparing the cost for the use of GPRS and Satellite data communication, the GPRS is considered a more suitable option and shall be used in this subsystem.

5.4 Staff Checking

Generally, tracking of staffs can be achieved with the use of RFID tags and GPS devices. Such system is usually used by supermarkets to track workers in the workplace, but has received a lot of privacy related complaint [14]. Going by the amount of related privacy issues with the RFID plus GPS device system and the fact that only the rest of the worker is required, two simple systems are looked into for this subsystem.

The first system uses a smart card which is required to be swipe through a scanner at the beginning of the work (sign-in) and at the end of the day work (sign-off). The time after the sign-off and before the next sign-in is considered as rest period.

The benefit of this system is that it is simple and does not interfere with the workers' privacy, however, with this system, it is impossible to know if a worker actually rested before next sign-in.

The second system, utilizes a motion sensor device, possibly in the form of a wristband, a tag or a pocket device which the workers are required to carry always. The device records the amount of inactive period and transfers this data wirelessly by bluetooth when the worker resumes for work.

For the system to serve its purpose, the workers should be required to honestly carry the device with them at all time and no more information than what is required should be collected to avoid invasion on workers privacy.

5.5 Bin Tracking and Weight Calculation

Tracking of bin and weight calculation: To calculate the weight of the bin, different approaches can be used; one of such is that of using the volume of the known type of waste to calculate the overall weight [15]. This method, would although not need any new equipments, but the process is slow and the efficiency is low as it would require each bin to be opened and the waste types listed out. Another possible option will be to redesign the bin to carry on board electronic scale (weighing equipment), which can allow the weight to be produce whenever required. But this option requires supply of new bin or adjustments to be made to the old ones. Considering associated cost, this option is dropped.

One more option and probably the best with regards to cost and efficiency will be to install an electronic weighing scale or system on the dustcart. This can be used in weighing the bin before it is emptied into the dustcart. To get the waste weight, the empty bin weight (mostly standard weight) is subtracted automatically from the total bin weight (empty bin plus waste).
To track the emptied bin, RFID tags (passive type) can be installed on every bin while the reader or scanner is installed along side with the weighing system (scale) on the dustcart. When the bin is weighed in the earlier stage, it is also scanned and the weight value is recorded along with the tag code. With this information, the amount of refuse collected from each house can be known (and used for billing later), also, whether or not a household bin was collected or not can be known and proved by this subsystem as codes of collected bins would have been recorded.

The limitation of this system is that proof of reason for the missed bin is not available (whether it was left out by the refuse workers or it was not available for collection from the household).

5.6 Real Time Central/ Control Office

Real Time central/control office: For feeding real time data to the central/control office for management reporting, the following options are considered.

5.6.1 Satellite communication: One of the application areas of satellite communication is data transfer. After data have been gathered by the other subsystems, they can be relayed back to control office by satellite data transfer; although the associated cost of this option is high, and the latency period (time delay) is high (more than 500ms for geostationary) and as such may not meet the real time data transfer requirement [16].

5.6.2 Mobile Broadband: Mobile broadband in other words are wireless internet access through cellular phones. The possible network collections that could be used are GPRS, 3G, LTE, WiMax and others. For this subsystem, the GPRS based wireless internet access will be used to transmit data to the back office because of the availability of mobile networks supporting the GPRS.

Although data transmission rate of GPRS is not as good as that of the satellite, 3G or LTE, the amount of data needed to be transmitted to the control office by individual dustcart is not very large, also the charges associated with GPRS is much lower than the other options and the latency time is not as high as that for satellite transmission.

5.7 Overall System

Based on the choices in the subsystems, the general waste collection system is built up of the below components.

Business Process Area	Mobile Technologies	Devices
Dustcart Tracking	Mobile Network Based GPS Tracking	GPS tracking device
Time Prediction and Route Designing	Mobile Network Based GPS Tracking	GPS tracking device and Optimization Software
Communication with Vehicle	GPRS	Messaging Device eg. Smart phone
Worker Monitoring	Bluetooth	Bluetooth enabled Motion Sensor
Bin Tracking and Weighing	RFID	RFID tags, scanner, electronic scale, smart phone
Real Time Data Transmission	Mobile Broadband by GPRS	Smart phone
Back Office Requirement		Computer Systems, Management Software, (Database, Route mapping, prediction and optimization software, GPS tracking viewer, communication and messaging software, monitoring software)

TABLE 1: System Components.

The overall system will make use of the above components with computer systems and management software installed at the control office.

6. FUTURE RESEARCH

This paper has researched into how mobile technologies can be used in solving different aspects of waste collection on a small scale, although it is possible for the system to be commercialized. Aspects that will need attention are the software and also the security issues and are currently been researched. Security measures will have to be taken in the storage of data (possibly having backups and guarding against attacks such as virus etc); also, information sent through wireless internet will need to be encrypted.

Developing countries that would benefit much from such a system might be limited by the reliability of mobile network services in those areas. These related issues are planned to be solved using cloud computing, which should provide a breakthrough in waste collection and find further applications in other waste management areas [17, 18].

7. CONCLUSION

In this paper, mobile technologies have been studies and used in conceptually designing a system solution to waste collection which is an important step in waste management.

In creating the system, a break down method was used; where individual problems were solved using subsystems which are then integrated together. In each subsystem, the strength and weakness of available mobile options were compared, and a suitable option chosen.

This system can be commercialized and could be very helpful in developing countries, though security issues, data collection and processing, and network connections along with signal issues would have to be further considered.

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9. APPENDICES

Case Study: Refuse Collection – Silverdale Waste

Silverdale Waste provides refuse collection services for the North Cumberland Waste Authority (NCWA). Silverdale have a fleet of 20 dustcarts (refuse collection vehicles) and only collect household refuse in the North Cumberland district which represents a 40km geographical area. The district is divided into 5 parts and each part has a dedicated refuse collection day. Two stations are operated with 10 carts each, one in the North of the district and one in the South. On average 8 carts are available for use each week; 2 being serviced or in the repair shop.

All systems are non-mobile at present with the only IT presence being a PC at each station which is used by the station manager for excel spreadsheets, email and a rudimentary database of historical collection records. There is no IT equipment on the dustcarts and the refuse workers use no IT equipment. Every month the station manager has the difficult task of providing performance statistics to the NCWA.

The household bins are typical wheelie bin designs.

Every week a house-holders bin will be collected by the refuse worker, emptied into the dustcart and then returned empty to the household. This is called a route.

The management at Silverdale Waste is conscious that the firm is not IT enabled and they have issues which they would like to see addressed. They have asked Cumberland Business Link to provide a consultant to review their business and how IT can help in the following business process areas:

Business Process Areas:

• Tracking the position of its fleet.

• Predicting how long a route will be and scheduling the use of dustcarts by designing routes.

• Redirect vehicles when necessary by being able to communicate with them.

• Making sure the company complies with the working time directive by enabling a check that each worker has had the statutory amount of rest.

• Calculations of bin weights and tracking of bins emptied.

• How real time data can be fed to back office systems for management reporting.