Technologies and Their Usage in Solid Waste Monitoring and Management Systems

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Abstract— In the background of prompt advancement, information and communication technology (ICT) has become an ineluctable part to plan and design of modern solid waste management (SWM) systems. Solid waste management (SWM) is a great concern for society health and environment of rural and urban area. In today life, solid management system has become a major problem for cities. This problem increase because of economic action and fast civilization Solid waste management is one of the major environmental problems facing most of the developed and developing countries. Government is also trying to resolve these issues. This study presents review of the existing ICTs. SWM systems to elaborate the issues and challenges towards using integrated technologies based system. The ICTs are divided into four categories spatial technologies, identification technologies, data acquisition technologies and data communication technologies to plan, monitor, collect and manage solid waste. In this paper, we discuss on the first three technologies while the forth one is employed by almost every system. This review gives an idea about the basics of available ICTs and their application in SWM to planning and design of new system.

Key words: Waste management, Smart city, Composting, SWM, ICT, Wireless sensor network

I. INTRODUCTION

The global production of MSW is about 1.3 billion tones/year i.e. 1.2 kg/capita/day. Ten years ago, waste generation rate was about 0.64 kg/capita/day i.e. 0.68 billion tones/ year. The solid waste generation will be 1.42kg/capita/day i.e. 2.2 billion tones/year from 4.3 billion of urban residents by the year 2025 (The World Bank, 2012). Solid waste management (SWM), is the one thing just about each municipality delivers for its habitants which is perhaps the significant municipal service for other complicated municipal services like health, transportation or education (Rajendran et al., 2013)

Solid waste is composed of gadgets (such as discarded computers, printers and mobile phones), and domestic waste, industries, construction material, medical waste, and agriculture wastes. The content of solid waste creates a difference between developing and developed countries. For example, solid waste in developing countries has a much larger proportion of organic or domestic waste than in developed countries. The aim behind the idea of building a smart city is to improve quality of life of citizens by using advance technologies to improve the efficiency of services. ICT allows city to interact directly with the community. To tell what the situation of city is, how the city is developing, and how to make better life. Help the use of advance technology, system and sensors, data are collected from peoples and objects then we processed in real-time.

Many kinds of businesses produce waste. For example, automobile vehicles and photo processing, dry cleaners centres may all generate waste. Some hazardous waste generates from larger companies such as electroplating companies, chemical manufacturers and oil refineries. These wastes may be initiate in different states gaseous, liquids, or solids. Depending on the state of the waste, treatment of waste processes of waste might be required.

Call monitoring system is providing the set of integrated tools which optimized to meet efficient handling of complaints, and automate processes like registering new complaints, managing existing complaints, automatic escalation of unresolved complaints, managing complaint statuses, performing number of consumer inquiries, handling of complaints by respective persons/departments and producing informative system. It allows all team members to work in a collaborative manner.

II. LITERATURE REVIEW

ICTs handle the increasing problems in SWM. ICTs are becoming more impressive due to the growing necessities for identification, analysis, communication, storage and automated data acquisition. The roles of these ICTs have been limited to stand-alone applications without cooperative effects. The ICTs for SWM can be classified into four categories: spatial technologies, identification technologies, data acquisition technologies and data communication technologies as shown in table 1. For monitoring, collecting, transporting, treating and managing the data ICTs technology is used. The SWM systems that are assembled by using technology are mainly implemented based on the first three categories such as systems based on spatial technologies, systems based on identification technologies and systems based on data acquisition technologies. Brief descriptions about the ICTs and their usage in solid waste monitoring, collection and management are discussed in the following sections.

ICT classification	ICT Sub-Class	Application
Spatial Technologies	GIS	Site selection; planning; management; estimation; optimization

	GPS RS	Route and collection optimization; vehicle tracking; planning; scheduling; billing Site selection; environmental impact assessment; features monitoring
Identification Technologies	Barcode RFID	Intelligent recycling; waste disposal; reduce landfill space; risk management Bin and driver tracking; optimization; sorting and recycling
Data Acquisition Technologies	Sensors Sorting Imaging	Sorting; optimization; moisture; energy and odor measurement; scheduling Waste sorting; route and collection optimization; monitoring
Data Communication Technologies	GSM/GPRS ZigBee Wi-Fi Bluetooth VHFR	Long range communication Short range communication Short range communication Short range communication Long range communication

Table 1:

III. SPATIAL TECHNOLOGIES

Spatial technologies are the widely-used ICTs in environmental modeling. Spatial analysis is very important for many environmental studies. These technologies are effective to handle complex spatial information. These technologies provide platforms for the integration of various models and interfaces. The major functions of this technology include the storing, capturing, analyzing and mapping of spatial data. The spatial dataset may contain attribute data, spatial topology, raster, features and even network datasets. Spatial technologies are classified in three main types such as geographic information systems (GIS), global positioning system (GPS) and remote sensing (RS). The following the three types of spatial technologies their applications in SWM systems and their deficiencies are briefly described.

A. Geographical Information System (GIS)

GIS, one of the most sophisticated spatial technology. It is a computer based information system. This technology is able to collect, store, manage, integrate, manipulate, analyze and display of spatial data known as geospatial or geographically referenced data. Normally, a GIS has four classes of components such as production of spatial data, management of data, cartography and display, and analysis of data (Lu et al., 2013). The production of spatial data includes data capture, quality inspection, input data and format conversion. In GIS, the spatial data may take two formats such as vector data or raster data. In vector data format, all vector characteristics are referenced to the same coordinate and maps are made of points, lines or polygons (Sanchez-Hernandez et al., 2007). In raster data format, the maps are made of as group of grid cells with each cell having a color value for presenting what lies where that cell is (Bishop et al., 2000). It is successfully used in applications, such as SWM, urban utilities planning, natural resources management, transportation, forestry, natural disasters prevention, geology and in many aspects of environmental modeling (Clarke, 1997).

B. Geographical Positioning System (GPS)

GPS is a global navigation and localization system. It is based on a multiple satellites and ground stations that are placed by the United States'. The GPS system is divided into three sub-systems - space sub-system (the satellites), control sub-system (the ground stations) and user sub-system (GPS receivers). The space sub-system contains 24 satellites that are functioning from 12,000 miles upon the Earth's surface (Kumar and Moore, 2002). These satellites are organized such a way, so that, GPS receiver from any place on earth can receive signals at any given time form as a minimum of four satellites. The satellites transmit radio signals with low power and require line-of-sight (Elena et al., 2002) The satellites are controlled by the control sub-system and provides accurate orbital and time information (Zhao, 2002). There have five stations, situated around the world. The user sub-system is every individual user with GPS who can make queries about his/her spatial information (Arvanitis et al., 2000) In (Faccioet al., 2011), the authors have developed a framework that focuses on GPS and other trace ability technology for the optimization of solid waste collection in terms of route and cost.

IV. IDENTIFICATION TECHNOLOGIES FOR SWM SYSTEM

In recent researchers and organizations involved in SWM have investigated different types of technology to increase the efficiency of waste management and automate the collection of bins (Gnoni et al., 2013). The proliferation of identification technologies, such has barcode and RFID technologies, brought a new strength to SWM systems (Lu et al., 2013).

A. Barcode

Barcode is an electronic data interchange medium that contains machine readable dichromatic mark that encodes information for objects labeling using an arrangement of geometric symbols (Lu et al., 2013). Barcode is a combination of black and white lines. The principal of barcode technology is called symbiology that defines the barcode .it determines the interpretation and mapping of the encoded data (Gao et al., 2007).

In (Saar et al., 2004), the authors developed a system that links existing bar codes on mobile phones to web sites containing disassembly information for European cell phones.

This technology has also used to build SWM systems with target to minimize avoidable waste (Li et al., 2003), reduce landfill space (Greengard,2010), risk management (Cronin et al., 2011) and facilitate advanced waste disposal (Hata, 2004).

B. Radio Frequency Identification (RFID)

RFID is an automated data collection technology. This technology used in radio frequency signals. It is a generic terminology. RFID used in that technologies which are based on radio waves and automatic identification or tracking of objects or assets and people. An RFID system consists of three main components such as transponder named as RFID tag, interrogator which is termed as RFID reader and host that is a data collection application in a device (such as computer) The read range of a reader varies and the RFID technology works from one inch to 100 feet or more (Finkenzeller, 2003).

In today life payment and waste collection are still manual and possible errors and mistakes common in manual operation. The RFID system automates the process. it reduces the driver's responsibility. Waste management efficiency is thus improved by applying RFID (Abdoli, 2009). In (Hannan et al., 2011), the authors have proposed a waste bin and truck monitoring system for Malaysia that enabled with RFID and ICTs.

The paper presents an integrated system that focused on RFID technology with GPS, GIS and camera. It helps in designing an intelligent monitoring system for bins and trucks. A novel integrated theoretical framework, a hardware architecture and an inference algorithm has been introduced in the proposed research. The model In corporate database which stores bin and truck information related with the bin and truck identity. It processes the date and time of waste collection, the bin status, the amount of waste transported and the truck GPS coordinates. Experimental results proved that the proposed monitoring system is stable and has high performance.

V. DATA ACQUISITION TECHNOLOGIES

Data Acquisition (DAQ) technology provides the link between the data-generating sensors and data-storing recording devices. DAQ can also provide the means for driving external actuators from a computer, by the generation of external excitation signals. DAQ technology includes both hardware and software. The emergence and rapid development of data acquisition technologies, manual acquisition of data has been substituted by automatic data acquisition because of its high efficiency, cheaper long-term operational costs and less man power requirement (Luet al., 2013). Based on the type SWM applications, the data acquisition technologies are classified into two categories sensors and imaging. A brief description of the data acquisition technologies and their types

A. Sensors

Author Fraden says A sensor is a device that perceives and measures real-world features, such as physical quantities or chemical properties, and converts them into signals that can be directly observed or adopted by another device. A sensor is mainly constructed by two elements sensing element and transducer element. In (Vicentini et al.,2009), the authors have implemented a sensitized waste collection bin for content estimation and collection optimization. The paper presents the design and implementation of a suitable urban solid waste system .it can predict the quantity and diversity of solid waste.

B. Imaging Technology

Imaging is the activities of sensing, capturing, storing, manipulating and displaying of digital image by synthesizing image sensors and post digital processing. Imaging is used to extract target or detect events from digital images (Arebey et al., 2012). Image processing has two main parts such as feature extraction and classification. Feature extraction is a broad part of the image processing research area. Many image processing techniques are used in image feature extraction. Images have various features, entropy, energy, power etc. The features are selected based on the output of the features how they keep differences within various images (Islam et al., 2014). In (Arebey et al., 2012), the authors developed a bin level detection model based on gray level co-occurrence matrix feature extraction approach and tested in Bangi, Malaysia

C. Data Communication Technologies

When modern communication technologies and internet did not use by everyone, the communications of data were usually performed by using floppy disks, CD-ROMs or any local Supervisory Control and Data Acquisition (SCADA) systems (Lu et al., 2013). Wireless communication technologies are mainly used In SWM applications. It includes GSM, GPRS and VHFR for long range communication and Wi-Fi, ZigBee and Bluetooth for short range communication.

D. GSM/GPRS

Global System for Mobile communications (GSM) is 2G type of network. Its start in 1982 at Europe. Now it is globally accepted standard for digital cellular communication technology. GPRS supports the networks based on the Internet Protocol (IP) and X.25 (Bettstette et al., 1999). General Radio Service (GPRS) is considered a 2.5G type of network.

E. ZigBee

The ZigBee technology developed by the ZigBee Alliance. An association of companies that are working together to develop standards for reliable, cost-effective, low-power wireless networking (Zigbee, 2008). Zig Bee builds upon the IEEE 802.15.4 standard that defines the physical layer (PHY) and medium access control sub layer (MAC) specifications for low data rate wireless connectivity that consume minimal power and costs low (Howitt and Gutierrez, 2003).

F. Wi-Fi

Wireless termed as Wi-Fi is a short range wireless communication technology. That is broadly used in the mobile connection of home and small office network we use it because of its flexibility and mobility. In recent years, the number of Wi-Fi access

point (AP) is increased rapidly. This makes the applications of wireless network more convenient and efficient. The official name is IEEE 802.11. It is consisting of more than 20 different standards. The most well-known standards are 802.11b and 802.11g that operate in the 2.4 GHz band and has a maximum data rate of 54 Mbps while coverage area within 250 m. Some consumer electronics use 802.11a which operates in 5 GHz band having a maximum data rate of 11 Mbps and same coverage limitation (Guo et al., 2012).

VI. CONCLUSION

This study reviewed the available ICTs and their applications in municipal SWM systems. The ICTs are classified into four technology spatial technologies, identification technologies, data acquisition technologies and data communication technologies. SWM systems are mainly progressed based on the first three classes. The spatial technologies include GIS, GPS and RS. The identification technologies contain barcode and RFID. The data acquisition technologies include sensing and imaging technologies. The data communication technologies include the short range and long range communication technologies. In ICTs, GIS is the mostly used technology that used to implement systems integrated SWM establishment and risk assessment. The GPS based SWM systems are used in collection vehicle tracking, route optimization, collection, monitoring and implementation of billing. Applications of RS based systems in SWM includes disposal site selection, environmental features and impact monitoring. Among the identification technologies, barcode based SWM system is used to implement intelligent recycling, minimize avoidable waste assessment. Later the barcode is replaced with RFID. Several challenges need to face to overcome these problems. Further research and development is very important to design and develop green ICT goods. With all these effort government policies will extract benefits from modern ICTs for the improvement of clean and green society.

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