Waste Management xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Review

Technologies and decision support systems to aid solid-waste management: a systematic review

Angelina Vitorino de Souza Melaré [a,*], Sahudy Montenegro González [b,*], Katti Faceli [b], Vitor Casadei [b]

[a] Faculdade de Tecnologia Dom Amaury Castanho – FATEC Itu, Brazil
[b] Federal University of São Carlos, Brazil

ARTICLE INFO

Article history:
Received 9 May 2016
Revised 30 September 2016
Accepted 27 October 2016
Available online xxxx

Keywords:
Solid-waste management
Decision support system
Operations research
Recycling
Information and communication technologies
Systematic review

ABSTRACT

Population growth associated with population migration to urban areas and industrial development have led to a consumption relation that results in environmental, social, and economic problems. With respect to the environment, a critical concern is the lack of control and the inadequate management of the solid waste generated in urban centers. Among the challenges are proper waste-collection management, treatment, and disposal, with an emphasis on sustainable management. This paper presents a systematic review on scientific publications concerning decision support systems applied to Solid Waste Management (SWM) using ICTs and OR in the period of 2010–2013. A statistical analysis of the eighty-seven most relevant publications is presented, encompassing the ICTs and OR methods adopted in SWM, the processes of solid-waste management where they were adopted, and which countries are investigating solutions for the management of solid waste. A detailed discussion on how the ICTs and OR methods have been combined in the solutions was also presented. The analysis and discussion provided aims to help researchers and managers to gather insights on technologies/methods suitable the SWM challenges they have at hand, and on gaps that can be explored regarding technologies/methods that could be useful as well as the processes in SWM that currently do not benefit from using ICTs and OR methods.

Contents

1. Introduction

One of the main concerns in society is the need for the development of a sustainable society, and this is triggered by environmental, social, and economic problems caused by global development (Seok et al., 2012). The growth in the global population, along with

* Corresponding authors.
E-mail addresses: angelinamelare@gmail.com (A. Vitorino de Souza Melaré), sahudy@ufscar.br (S. Montenegro González), katti@ufscar.br (K. Faceli), vitor.casadei@gmail.com (V. Casadei).

http://dx.doi.org/10.1016/j.wasman.2016.10.045
0956-053X/

its migration to urban centers and accompanying consumption trends, has led to an uncontrolled exploitation of natural resources, emission of gases harmful to health, and the appearance of several environmental problems such as climate change, extinction of species, and an increase in solid-waste generation (Phillis et al., 2011; Rio+20, 2012; United Nations Report, 2005).

According to the triple bottom line (formed by the economic, environmental, and social pillars), the economic performance of each country should (1) take into account the value of the environment and people, (2) promote social responsibility, and (3) promote the population's quality of life (Seok et al., 2012; Ahmed and Sundaram, 2012).

Research and projects that are aimed at alleviating environmental problems have been highlighted by the scientific community, in global meetings, such as the UN Conference on Sustainable Development Rio+20 (2012), and in reports, such as the Millennium Development Goals Report of the United Nations (UN) (United Nations Report, 2005). In these meetings, goals and principles are defined to ensure environmental sustainability in such a way that people have quality of life without compromising the needs of future generations (Rio+20, 2012). Several countries have committed to these principles and to international agreements, incorporating them into domestic development strategies, and in developing technical standards and legislation (Phillis et al., 2011).

At Rio+20, solid-waste management was one of the topics included among the nine dimensions on which there was a focus (Rio+20, 2012). This topic is also featured in the scientific community, and there are articles that describe the operational, environmental, and economic problems of such management (Faccio et al., 2011). Waste management is complex and encompasses a set of actions carried out directly or indirectly in the stages of planning, collection, transport, transshipment, and processing of waste, and residues (Brasil, 2010).

In the scientific community, there are publications that report the application of Information and Communication Technologies (ICTs) and methods of Operations Research (OR) for Solid-Waste Management (SWM). The methods that help the decision-making process, such as Multi-Criteria Decision Analysis (MCDA), allied to ICTs favor the development of efficient solutions in planning and management, assisting managers in environmental issues.

Several proposals integrate technologies, such as Radio-frequency identification (RFID), Global Positioning System (GPS), and Geographic Information System (GIS), for example, for monitoring solid waste collection trucks and containers. In the case of the containers, those technologies have been used to automatically detect the level of the container combining the use of machine learning and image processing techniques. GIS allied to MCDA have been used to assist managers in the decision-making process regarding the determination of a suitable place to install a new landfill, or the determination of the best localizations and adequate capacity of waste-collection containers. Genetic algorithms have been used to optimize the routes used for solid-waste collection, seeking to improve the population's well-being, and minimizing fuel consumption and pollution (noise and visual). The solutions are not limited to solve current problems, but also develop scenarios and products thinking about the future, which is the case, for example, of the reverse logistics process and design of electronics.

The general aim of this paper is to map the world research scenario on decision support systems aiming solid-waste management. For such, we present a systematic review on decision support systems applied to solid waste management using ICTs and OR in the period of 2010–2013. As a methodological scientific review of literature, this systematic review was formally planned and executed, and can be replicated and continued by other researchers. With its use, we expect to contribute with future studies performed in the field of solid-waste management, as well as to help researchers and managers to gather insights on technologies/methods suitable for the SWM challenges they have at hand, and on gaps that can be explored regarding technologies/methods that could be useful, or the processes in SWM that currently do not benefit from using ICTs and OR methods.

Performing the review, we identified eighty-seven relevant publications using a great variety of ICTs and OR methods for several processes related to SWM. To improve the overall comprehension of the review, we grouped the identified SWM processes into six categories and classified the publications according to them. The processes are management of collection, route, and transport; management and monitoring of containers; recycling of solid residues and management of electronic waste; public administration and sustainable development; forecasting and planning methods; and determination of waste-disposal sites.

Based in the findings of the review, we performed a statistical analysis of the relevant publications focusing on the ICTs and OR methods adopted for SWM, the processes of solid-waste management where they were adopted, and which countries are investigating solutions for the management of solid waste. We also provided a detailed discussion on how the ICTs and OR methods has been combined in the solutions.

This review is organized into several sections, starting with the contextualization of solid-waste management and its relation to decision support systems in Section 2. Next, in Section 3, we describe the systematic review methodology. Section 4 provides the answers of the research questions by discussing and analyzing the selected publications. Finally, Section 5 concludes the paper and presents some identified gaps.

2. Contextualization of solid-waste management and decision support systems

Increasing waste generation is an issue reported by many countries such as China, the United States, Canada, the Philippines, Malaysia and many European countries (House et al., 2011; Islam et al., 2012; Fan et al., 2010). For example, in Canada, there was an increase of 5 million of tons in 2006 compared to 2002, and in the United States, from 1990 to 2006, the increase was 31 million of tons. This increase is a serious concern and several countries have been carrying out simulations to estimate waste generation in order to better understand the problem and propose adequate means of disposal or to slow down this increase (Hannan et al., 2013; Malakahmad and Khalil, 2011).

The literature shows that the lack of planning and unsuited infrastructure for disposal of solid waste leads to a large amount of waste being dumped in public areas without ground preparation, such as open air dumps and rivers. In Brazil, for example, urban solid waste generation increased 1.3% in 2012 and 6.2 million of tons of Municipal/urban Solid Waste (MSW) were no longer collected (ABRELPE e PLASTIVIDA, 2012). Also, in the Philippines, in 2006, of the 300 tons of waste generated per day, only 220 tons were collected (Iloilo City, 2006).

There is a contrast in the management of waste and its final destination in several countries. There are countries more mindful of the importance of recycling, making use of legal and technological solutions to increase recycling. For example, Germany, Denmark, Holland and Belgium are featured in the recycling of construction waste (Banias et al., 2011). In Canada, around to 26% of waste collection was recycled in 2012 (Hoornweg and Bhada-Tata, 2012). Oppositely, in other countries the recycling initiatives are still modest. In Brazil, in 2010, for example, the highest waste collection rate (55%) represented waste sent to landfill and only 1.2% was sent for recycling (Instituto Brasileiro de Geografia e Estatística, 2008). In Mexico, Czech Republic, Poland, Hungary

Please cite this article in press as: Vitorino de Souza Melaré, A., et al. Technologies and decision support systems to aid solid-waste management: a systematic review. Waste Management (2016), http://dx.doi.org/10.1016/j.wasman.2016.10.045