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Multiple stakeholders in multi-criteria decision-making in the context of Municipal Solid Waste Management: A review

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ABSTRACT

Municipal Solid Waste Management (MSWM) is a complicated process that involves multiple environmental and socio-economic criteria. Decision-makers look for decision support frameworks that can guide in defining alternatives, relevant criteria and their weights, and finding a suitable solution. In addition, decision-making in MSWM problems such as finding proper waste treatment locations or strategies often requires multiple stakeholders such as government, municipalities, industries, experts, and/or general public to get involved. Multi-criteria Decision Analysis (MCDA) is the most popular framework employed in previous studies on MSWM; MCDA methods help multiple stakeholders evaluate the often conflicting criteria, communicate their different preferences, and rank or prioritize MSWM strategies to finally agree on some elements of these strategies and make an applicable decision. This paper reviews and brings together research on the application of MCDA for solving MSWM problems with more focus on the studies that have considered multiple stakeholders and offers solutions for such problems. Results of this study show that AHP is the most common approach in consideration of multiple stakeholders and experts and governments/municipalities are the most common participants in these studies.

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Abbreviations: MSW, Municipal Solid Waste; MSWM, Municipal Solid Waste Management; MCDA, Multi-criteria Decision Analysis; NGO, non-governmental organization; AHP, Analytical Hierarchy Process; ANP, Analytical Network Process; MAUT, Multi-Attribute Utility Theory; PROMETHEE, Preference Ranking Organization METHod for Enrichment Evaluations; GAIA, geometrical analysis for interactive aid; ELECTRE, ELimination Et Choix Traduisant la REalité; TOPSIS, Technique for Order Preference by Similarity to Ideal Solution; GIS, geographic information system; NSERC, Natural Sciences and Engineering Research Council of Canada.

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1. Introduction

Municipal Solid Waste (MSW) is a mixed and yet critical stream. In the past ten years, global MSW generation has increased from 0.68 billion tonnes per year (0.64 kg of MSW per person per day) to 1.3 billion tonnes per year (1.2 kg per person per day) and it is likely to reach 2.2 billion tonnes per year by 2025 (The World Bank, 2012). In Canada, MSW generation was considerably high at 2.1 kg per person per day in 2008 (Statistics Canada, 2012). To avoid human health and environmental issues accompanying poor management of the disposed MSW, both governments and scholars search for effective strategies and solutions.

Municipal Solid Waste Management (MSWM) is a complex process including waste collection routes, transfer station locations (Dewi et al., 2010), treatment strategy, treatment plant location, and energy recovery. In order to design and implement a suitable MSWM, decision-makers should set local and regional goals on all or some of these stages and then plan a strategy accordingly; but, most studies on MSWM strategies have only focused on two main stages: the waste treatment strategy and the location of treatment plant because of the magnitude of their ecological and financial impacts.

Waste treatment is the core mean to reach the MSWM objectives including protection of human health and environment, economic development, and fulfillment of social and regulatory requisites. There are several treatment options for MSW; thus, choosing the 'optimal' or the best available option(s) usually involves decisions on the technology, location (Achillas et al., 2013), and capacity of the treatment plant. These decisions are often made by considering various criteria such as environmental impacts (e.g., global warming, human health risks, resource depletion, ecosystem damage), associated economic costs and benefits, and regional characteristics (e.g., waste generation rate, and political and social factors). Some of the most applied waste treatment strategies include landfilling and waste-to-energy technology.

Since the ranges of waste treatment and in general MSWM strategies are quite diverse, choosing a single MSWM approach or an arrangement that satisfies the decision-makers' objectives is challenging. Decision-makers need to compare the MSWM strategies based on their level of performance in fulfilling the defined criteria. Accordingly, there is a need to develop a decision support framework to compare the performances in one criterion to another. Hence, selecting the best and most effective MSWM system(s) requires the application of an integrated framework in an effective manner (Caputo and Pelagagge, 2002).

A procedure that can guide and support to form a decision is known as decision support (Sullivan, 2002; Bardos et al., 2001). Consequently, a decision support framework is defined as an outlined procedure that supports individuals or groups in their decisions toward achieving specific objectives, guides them to the best available solution, and has enough flexibility to be modified (Karmperis et al., 2013). Decision support frameworks in MSWM study selected waste streams and compare the existing waste management options to guide decision-makers select the best available and applicable option(s) (Morrissey and Browne, 2004).

Various frameworks have been developed to support decision-making in MSWM. They initially optimized individual sections of MSWM such as plant locations or delivery routes and later analyzed MSWM as a system (Hung et al., 2007). Dewi et al. (2010) categorizes these frameworks into *cost-based*, *environment-based*, and *multi-criteria-based*. Cost-based models evaluate alternatives based on monetary values. Environment-based models evaluate the use of natural resources and potential impacts on the environment. Multi-criteria-based models including Multi-criteria Decision Analysis (MCDA) methods consider and integrate often conflicting criteria from various dimensions and therefore deliver more robust decisions than the two previous methods (Morrissey and Browne, 2004).

MCDA techniques and methods are formal approaches developed for problems such as MSWM that have greater impacts on people and environment and therefore may involve more criteria and viewpoints (Belton and Stewart, 2001). More information on some of the more common MCDA methods can be found in Appendix.

The countless combinations of many criteria of cost, safety, productivity, environmental impacts, location and so on in waste management leave no choice for decision-makers but to choose among available alternatives (Wiecek et al., 2008). Therefore, several criteria should compete in a decision-making process to ultimately reach a valid and steady state balance that satisfies all decision-makers. MCDA introduces a wide range of methodologies that can efficiently help decision-makers with such complex decision-making problems (Zopounidis and Doumpos, 2002).

Around the world, collection, diversion (i.e. recycling and composting), and disposal operations are often run by municipalities/governments. In addition, ministries, investors, NGOs, and neighbourhood population can also be involved or impact selection of a MSWM strategy. In other words, the stakeholders are the individuals or groups that are whether affecting, being affected by, or both affecting and being affected by MSWM decisions (Banville et al., 1998).

Municipalities are conscious of human health risks and environmental impacts associated with poor waste management strategies (Joseph, 2006) and they have the right intentions to make efforts to prevent these risks. In order to expand their options and increase their financial and human resources, municipalities look for other stakeholders to partner and share responsibilities with (Joseph, 2006; Contreras et al., 2008). Municipalities should often negotiate with these stakeholders for satisfying and fair shares of costs and benefits from these partnerships (Reza et al., 2013).

One of the main problems in MSWM is lack of effective communication between various stakeholders involved (Bani et al., 2009). Open discussion can collect the society aspirations but leads to bottom-up approach; open discussions can also take time and end in non-applicable decisions. MSWM strategies demand a decision support framework that facilitates communication among stakeholders and provides solution for conflicts among stakeholders. Seeking an optimum might be the goal of traditional optimizing tools, but MCDA can go further and create an accommodation that satisfies stakeholders and helps them communicate their different preferences and reach an agreement.

Morrissey and Browne (2004) argue that decision support frameworks for waste management should focus more on improving the participation of relevant stakeholders instead of just technical assessments. Achillas et al. (2013) also believe that effective waste management needs consideration of stakeholders' dialogues. Joseph (2006) and Joseph et al. (2012) suggest sustainable waste

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