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Multicriteria decision making in selecting best solid waste management scenario: a municipal case study from Bosnia and Herzegovina

Branko Vučijak [a, *], Sanda Midžić Kurtagić [a, b], Irem Silajdžić [b]

[a] Faculty of Mechanical Engineering, Sarajevo University, Vilsonovo šetalište 9, 71000 Sarajevo, Bosnia and Herzegovina
[b] Hydro Engineering Institute Sarajevo, Stjepana Tomića 1, 71000 Sarajevo, Bosnia and Herzegovina

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ABSTRACT

In modern challenging environment, decision makers often need fast and effective tools to quickly model and optimize several decision alternatives and then compare them according to various preconditions or performance criteria. Specifically, efficient solid waste management requires responsible administration to implement detailed screening of needs and desired development directions, followed by decision on the implementing measures. Such process results with a number of various solid waste management scenarios, often with mutually conflicting objectives or expected results. These scenarios affect different range of population, relate to diverse problems, vary in costs levels and time needed to become effective.

When selecting only one from various scenarios, different groups of decision-makers are involved. Decision-making has to take into account usually conflicting technological, economic, social and environmental objectives. Single-criterion decision-making based on available financial resources as a sole criterion does not respond to such requests.

This paper demonstrates the reliability of use of multi-criteria decision making tool for the purpose of selecting the best municipal solid waste management scenario among six different alternatives. The multi-criteria decision making tool enables decision makers to make informed decisions and achieve optimal results.

1. Introduction

1.1. Problem context

The main objective of solid waste management is to protect human health and the environment, and to preserve resources. The European Union (EU) waste policy aims to reduce waste production per capita, increase use of waste as a resource, make recycling attractive to both private and public sector, and eliminate need for disposal (European Commission 2011, 2013). The EU Directive 2008/98/EC on Waste sets targets for waste reduction in the EU:

- on the basis of biodegradable municipal waste generated in 1995, the biodegradable municipal waste going to landfill must be reduced to 35% by 16 July 2016;
- recycling of municipal solid waste must be increased to a minimum of 50% by weight;
- recycling of construction and demolition waste must be increased to a minimum of 70% by weight.

One of strategic directions that municipal authorities can choose is to implement separate collection and waste recycling system that could help in reducing amount of waste for landfilling, decrease frequency of transport to the landfill and overall costs of the disposal, while at the same time generating benefits for collection companies. The separate collection can be based on several

Abbreviations: AHP, analytical hierarchy process; ANP, analytical network process; ELECTRE, elimination Et Choix Traduisant la Realité; EU, European Union; MAUT, multiattribute utility theory; MCDA, multicriteria decision analysis; MOLP, multi-objective linear programming; MSWM, municipal solid waste management; PROMETHEE, preference ranking organization method for enrichment evaluations; SMART, simple multi-attribute rating technique; TOPSIS, technique for order preference with similarity to ideal solution; VIKOR, Vlšekriterijumsko KOmpromisno Rangiranje – multicriteria optimization and compromise ranking; WMS, waste management strategy.

* Corresponding author. Tel.: +387 33 729 800.
E-mail addresses: vucijak@mef.unsa.ba, bvucijak@gmail.com (B. Vučijak), midzic@mef.unsa.ba (S.M. Kurtagić), irem.silajdzic@heis.ba (I. Silajdžić).

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scenarios depending on the local situation and available infrastructure. It may involve waste separation in recycling yards, two bins municipal solid waste collection system for individual households, home composting, sorting stations and combination of these with the remaining fraction being disposed at regional landfill.

The selection of most efficient scenario requires responsible administration to implement detailed screening of needs and desired development directions, followed by decision on the implementing measures. Very often different scenarios affect different range of population, relate to diverse problems, vary in costs levels and time needed to become effective and most often they have conflicting objectives within the selected set of criteria.

Thus, in modern challenging environment, decision makers often need fast and effective tools to quickly model and optimize several decision alternatives satisfying defined preconditions (meeting the set constraints) and then compare them according to selected performance criteria.

Multicriteria decision analysis (MCDA) is a tool that incorporates value judgements of individual decision makers or multiple stakeholders in order to reach optimal decisions. MCDA tools utilize different optimization methods to rank alternatives, in order to select a single optimal alternative or to differentiate between acceptable and unacceptable ones. Alternative options are compared for their consequences (including environmental) and ranked based on a set of preselected criteria (Hermann et al., 2007).

As in most multicriteria optimization problems, it is not to expect that all key criteria can be optimized simultaneously and for the same selection; conveniently criteria are conflicting and better choice for one leads to worsening of another. Thus, an academically certified tool is needed to support the most appropriate selection between the alternatives valuated based on the set of criteria. This tool is considered to be multicriteria optimization process (multicriteria analysis), or at wider perspective, multicriteria decision making.

Decision on use of an appropriate tool is a challenge for itself. First, the problem needs to be defined clearly, then realistic alternatives identified, actors involved in the decision-making recognised, and appropriate evaluation criteria selected. Then the evaluation can be done using appropriate MCDA method that should aggregate the performance of each alternative, with or without weighting of the selection criteria. In the environmental field, MCDA is used for analysis of different environmental systems with the ultimate aim to evaluate a problem by giving an order of preference to multiple alternatives based on several criteria that may have different values.

The objective of this paper is to demonstrate use of MCDA for selection of appropriate municipal solid waste management (MSWM) scenario that includes waste separation and recycling component on a case study from one municipality in Bosnia and Herzegovina. Selection of criteria and their valuation is based on principles of exhaustiveness, cohesiveness and non-redundancy, as proposed by Laforest et al. (2013). Six different MSWM scenarios (alternatives) that should help implementation of regional MSWM concept were analysed, ranked, and evaluated.

1.2. Literature review

Frequently used MCDA tools include AHP (Analytical Hierarchy Process), ANP (Analytical Network Process), MAUT (Multiattribute Utility Theory), PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations), ELECTRE (Elimination Et Choix Traduisant la Realité), SMART (Simple Multi-Attribute Rating Technique), MOLP (Multi-objective Linear Programming), TOPSIS (Technique for Order Preference with Similarity to Ideal Solution) and other forms of linear programming (LP).

Several authors addressed application of multicriteria decision analysis in different environmental areas. Huang et al. (2011) reviewed 312 papers published between 2000 and 2009 reporting about MCDA applications in the environmental field, classified by their application area, decision or intervention type and the MCDA methods used. Among the MCDA methods reviewed, AHP/ANP dominates with 48% in all environmental areas.

Use of MCDA in waste management was documented by 30 papers. Of that, 15 papers reported about use of AHP or ANP method, 5 used MAUT, 4 used PROMETHEE, 1 used multiple methods, 1 was just a review without practical example, and 4 were classified as other.

Soltani et al. (2015) underlined that the municipal solid waste management is a complicated process that involves multiple environmental and socio-economic criteria. They confirmed that the decision-makers need decision support frameworks that can guide in defining alternatives, selecting relevant criteria relevant criteria and their weights, and finding a suitable solution. The paper goal was to identify approaches and trends in considering various stakeholders in municipal solid waste management decision making situations using multicriteria decision analysis based decision support frameworks. Related literature review was performed on peer-reviewed journals and conference proceedings published until the end of 2013, included total of 68 studies. According to the review, AHP (including ANP and fuzzy AHP) was the most dominant MCDA method, PROMETHEE was an emerging method, and ELECTRE was the most consistently used method, while in the last period the diversity of methods was expanding to include some new methods as well.

The reviews of Huang et al. (2011) and Soltani et al. (2015) show that number of studies exploring use of MCDA techniques tremendously increased in the past decade. It is interesting to note that none reported use of VIKOR method in selection of best solid waste management system.

As indicated above, the AHP is the most widely applied method to a wide variety of decision-making problems, including the environmental related ones. This method was created by Saaty in 1980 as a structured but flexible technique for making decisions in a multicriteria context. The best alternative is selected from a given set of alternatives by considering decision-makers' judgements on pairwise comparisons of the alternatives for each of the criteria. The popularity of AHP method is also confirmed in review paper of Govindan et al. (2013) who examined 33 journal articles on use of MCDA in evaluation and selection of right supplier using green criteria. The ANP is a recently developed multicriteria decision making tool that extends the AHP. Guerrero-Baena et al. (2015) successfully implemented ANP to prove it is robust and reliable tool for evaluation and prioritization of environmental management system alternatives in for-profit firms.

Additional to above mentioned MCDA tools, Hokkanen and Salminen (1997) used ELECTRE III in the context of choosing most appropriate solid waste management system in the Oulu region in Finland. They reported that ELECTRE III proved useful, especially when dealing with environmental problems involving many decision-makers, and in cases where the outcomes of the various alternatives remain to some degree uncertain.

Khalili and Duecker (2013) also addressed application of multicriteria decision analysis in design of sustainable environmental management systems, which are inherently multi-objective processes that require joint considerations of different environmental, industrial, economic and social criteria groups in all stages of decision making. They stressed that the inclusion of economic and social criteria, and the need for the involvement of multiple