Waste Management xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Waste Management

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

Multi-criteria group decision making for evaluating the performance of e-waste recycling programs under uncertainty

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ARTICLE INFO

Article history:
Received 18 November 2014
Accepted 23 February 2015
Available online xxxx

Keywords:
E-waste recycling programs
Intuitionistic fuzzy numbers
Multi-criteria analysis
Group decision making
Performance evaluation

ABSTRACT

This paper presents a multi-criteria group decision making approach for effectively evaluating the performance of e-waste recycling programs under uncertainty in an organization. Intuitionistic fuzzy numbers are used for adequately representing the subjective and imprecise assessments of the decision makers in evaluating the relative importance of evaluation criteria and the performance of individual e-waste recycling programs with respect to individual criteria in a given situation. An interactive fuzzy multi-criteria decision making algorithm is developed for facilitating consensus building in a group decision making environment to ensure that all the interest of individual decision makers have been appropriately considered in evaluating alternative e-waste recycling programs with respect to their corporate sustainability performance. The developed algorithm is then incorporated into a multi-criteria decision support system for making the overall performance evaluation process effectively and simple to use. Such a multi-criteria decision making system adequately provides organizations with a proactive mechanism for incorporating the concept of corporate sustainability into their regular planning decisions and business practices. An example is presented for demonstrating the applicability of the proposed approach in evaluating the performance of e-waste recycling programs in organizations.

1. Introduction

End-of-life electrical and electronic equipment, also known as e-waste, is the fastest growing waste stream in the world nowadays at an alarming growth rate of 3–5% per year (Afroz et al., 2013; Dwivedy and Mittal, 2013). Globally, about 30–50 million tons of e-waste are disposed each year due to the widespread adoption of electronics in consumer products and the accelerating technological change in today's dynamic environment (Menikpura et al., 2014). The increasing amount of e-waste presents a serious challenge for organizations in their active pursuit of sustainable development. As a result, it is critical for individual organizations to adequately adopt appropriate programs and approaches for reducing the negative impact of e-waste on the environment.

Recycling is widely known to be an environmentally-friendly strategy and the most appropriate approach to effectively manage e-waste for minimizing its negative impact on the environment (Oguchi et al., 2013). The popularity of recycling for effectively managing e-waste is due to the benefits that it can provide to individual organizations. Recycling, for example, is cost effective as it can help to reduce the costs of managing and handling waste in the organization. It can reduce the use of land for landfills in a society which is the common way of waste treatment nowadays. This in turn can reduce the negative impact of waste through landfills on the environment (Mulliner et al., 2013). To be economically viable, environmentally friendly, and socially responsible, organizations need to use structured approaches to evaluate the performance of existing e-waste recycling programs with respect to the interest of various stakeholders in a group decision making environment so that the most appropriate e-waste recycling program can be adopted in a specific situation.

Evaluating the performance of alternative e-waste recycling programs is complex and challenging. It often involves (a) multiple decision makers, (b) multiple evaluation criteria, and (c) subjective and imprecise assessments. Much research has been done on the development of appropriate approaches for evaluating the overall performance of e-waste recycling programs with respect to the overall sustainability performance objective of an organization from different perspectives (Ekmekcioglu et al., 2010; Kim et al.,

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http://dx.doi.org/10.1016/j.wasman.2015.02.035
0956-053X/

2013; Li and Tee, 2012). Ekmekcioglu et al. (2010), for example, apply the technique for order preference by similarity to ideal solution (Deng et al., 2000) for dealing with the e-waste recycling program performance evaluation problem. Linguistic variables are used to assess the relative importance of all the evaluation criteria and the performance rating of each e-waste recycling programs with respect to each criterion, leading to the development of a weighted fuzzy decision matrix in a given situation. A closeness coefficient is calculated for determining the ranking order of all the e-waste recycling programs across all the criteria. This approach is effective and efficient for solving the e-waste recycling program performance evaluation problem under some circumstances. It, however, is inflexible in the weight elicitation process and very demanding on the consistency checking in the subjective evaluation process.

Kim et al. (2013) propose an integrated approach using Delphi and the analytic hierarchical process (AHP) (Deng, 1999) for evaluating the performance of the recycling programs under uncertainty. The Delphi method is used for identifying the appropriate evaluation criteria in order to adequately consider the interest of various stakeholders in the decision making process. AHP is used for determining the relative importance of the evaluation criteria and the performance rating of alternative recycling programs. The overall performance of each recycling program across all the criteria is then determined by effectively aggregating the criteria weights and the performance ratings of the recycling program with respect to individual evaluation criteria based on the utility theory (Yeh et al., 2010; Wibowo and Deng, 2012). The approach is effective as it is capable of assessing all the criteria importance in a systematic manner. It, however, suffers from several limitations including the amount of time consumed in applying the Delphi method for identifying the evaluation criteria and the complexity to use the method for determining the overall ranking of individual recycling programs across all the evaluation criteria.

Li and Tee (2012) develop a mixed integer multi-objective linear programming approach for dealing with the problem of evaluating the performance of e-waste recycling programs. With the use of this approach, the economic, environmental and health perspectives of the e-waste recycling program are adequately considered, and both objective and subjective data are simultaneously used in the evaluation process. The approach is effective for addressing the problem of evaluating the e-waste recycling program performance with respect to the multi-dimensional nature of the evaluation process. This approach, however, is undesirable in some situations due to its inability for the decision maker to set up priorities among the objectives.

A decision support system (DSS) is a computer-based information system for supporting decision making activities in situations where it is impossible or not desirable to have an automated system for performing the entire decision making process (Deng and Wibowo, 2008). It is a useful tool that uses computers to (a) assist managers in their decision making processes for solving semi-structured problems, (b) support, rather than replace, managerial judgments, and (c) improve the effectiveness of decision making rather than its efficiency (Wibowo and Deng, 2013).

The application of a DSS for solving various decision making problems has become increasingly popular nowadays due to its flexibility and adaptability for tackling various decision situations (Carlsson and Turban, 2002; Demesouka et al., 2013; Sprenger and Monch, 2014). Numerous applications can be found in the existing literature for solving the decision problems of various kinds. Demesouka et al. (2013), for example, apply a DSS for conducting a suitability analysis for selecting a municipal solid waste landfill site. Sprenger and Monch (2014) develop a DSS for solving the cooperative transportation problem. El-Gafy et al. (2014) use a DSS for addressing the water irrigation problem in Egypt. These studies above show that the development and adoption of DSS for addressing various decision problems is of great benefits in real world settings. There are, however, still various challenges existent in dealing with real world decision problems, in particular for evaluating the performance of available e-waste recycling programs including (a) the need for adequately addressing the interest of multiple decision makers in a multi-criteria decision making environment, (b) the presence of the subjectiveness and imprecision inherent in the human decision making process, and (c) the cognitive demand on the decision makers in the decision making process.

This paper formulates the process of evaluating the performance of e-waste recycling programs as a multi-criteria group decision making problem, and presents a multi-criteria group decision making approach for evaluating the performance of e-waste recycling programs under uncertainty in an organization. Intuitionistic fuzzy numbers are used for representing the subjective and imprecise assessments of the decision makers in evaluating the relative importance of the evaluation criteria and the performance rating of individual e-waste recycling programs with respect to individual evaluation criteria. An interactive fuzzy multi-criteria decision making algorithm is developed for facilitating consensus building in a group decision making environment to ensure that all the interest of individual decision makers have been appropriately considered in evaluating the performance of alternative e-waste recycling programs with respect to their corporate sustainability objective. The developed algorithm is then incorporated into a multi-criteria DSS for making the overall performance evaluation process effective and simple to use. An example of the problem of evaluating the e-waste recycling program performance is presented to demonstrate the applicability of the proposed approach for solving real world e-waste recycling program performance evaluation problem.

In what follows, we first present an overview of the related research on the performance evaluation of e-waste recycling programs. We then present an interactive fuzzy multi-criteria decision making algorithm which is further incorporated in a DSS for solving the problem of evaluating the performance of e-waste recycling programs in organizations. Finally, we present an example for demonstrating the applicability of the multi-criteria group decision making approach in solving the real world problem of evaluating the performance of e-waste recycling programs.

2. Performance evaluation of e-waste recycling programs

Sustainability is becoming increasingly important to every organization nowadays due to the rapidly growing world population (Lohri et al., 2014), the increasing industrial production activities which heavily rely on the consumption of non-renewable resources and the rapid development of emerging economies (Gallego, 2006; Deng, 2015). Organizations are under increasing pressure to meet government environmental regulations and compliance standards (Zheng et al., 2013), to mitigate the environmental impact of their operations, and to address the environmental concern of various stakeholders (Figge and Hahn, 2006) while at the same time increasing their profitability (Mallawarachchi and Karunasena, 2012) and improving their competitiveness (Menikpura et al., 2014; Moller and Schaltegger, 2005; Zabaniotou et al., 2014). To effectively achieve the organizational sustainability objective in a dynamic environment, recycling programs are widely adopted as one of the appropriate approaches in various organizations for adequately addressing the sustainability concerns of various stakeholders (Dwivedy and Mittal, 2013; Oguchi et al., 2013; Vachon and Klassen, 2008).

There are many factors that influence the performance of e-waste recycling programs in organizations (Afroz et al., 2013;

Please cite this article in press as: Wibowo, S., Deng, H. Multi-criteria group decision making for evaluating the performance of e-waste recycling programs under uncertainty. Waste Management (2015), http://dx.doi.org/10.1016/j.wasman.2015.02.035