A fuzzy multiple criteria approach for environmental performance evaluation in the food industry

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Abstract. An important tool for the evaluation and documentation of a successful environmental management system is the Environmental Performance Evaluation (EPE). EPE is generally defined as a continuous internal process and management tool that using indicators evaluates the environmental management system of an organization and compares past and present performance. Relevant international standards such as ISO 14031-14032 describe the categories of performance indicators; however they do not determine a specific framework for the development, measurement and evaluation of these indicators. The main aim of this study is to present an EPE methodology based on the fuzzy UTASTAR method. Fuzzy UTASTAR is an extension of the well-known UTASTAR method capable to handle both ordinary (crisp) and fuzzy evaluation data. To demonstrate the application of the methodology, a case study is presented, where fuzzy UTASTAR is used in the frame of the EPE of a mills industry.

Keywords: Fuzzy UTASTAR, Environmental Performance Evaluation, Environmental Performance Indicators, Environmental Management Systems.

1 Introduction

Environmental concerns present a high and constantly increasing trend with the responsibility for its protection to lie not only to public authorities but also to companies and organizations in general. Irrespective of their size and type of activity, organizations are nowadays urged by their customers to offer products and services, which not only comply with their expectations with respect to use, but are also friendly to the environment. The environmental profile has emerged as a powerful communication tool, and its importance for all internal and external parts that comprise the environment of an organization increases continuously. Industry, in particular, which is responsible for a large part of the pollution and depletion of natural resources and energy, is called to modify its public image by increasing its sensitivity to environment-related issues. To this end and in order to clearly demonstrate their engagement to environmental-friendly policies and respective activities, organizations are nowadays developing, adopting and maintaining Environmental Management Systems (EMSs).

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EMSs offer multiple benefits to organizations as, beyond environmental protection, they cover issues such as compliance to legislation and formal regulations, prediction of future corrective actions, productivity increase, safety, employee protection and satisfaction, estimation of required costs and reduction of operational costs, and promotion of an improved organization image.

As part of their EMS, some organizations introduce formal procedures aimed at providing them with reliable data and information so as to enable and easy management decisions concerning their environmental performance. These procedures, which are collectively known as Environmental Performance Evaluation (EPE) assists them in identifying their important environmental aspects and in defining all necessary actions so as to achieve their environmental objectives and targets in a continuous basis (Kuhre, 1998).

Despite its widely acknowledged benefits, EPE is neither an easy nor a straightforward task due to the high level of required effort and resources. And although ISO has developed a standard, ISO 14031 (International Organization for Standardization, 1999, 2004), specifically aimed at assisting organizations in this difficult endeavor, EPE still remains an optional task.

The application of the UTA methods in environmental management problems is rather limited and it is mainly focused on landfill selection, wastewater treatment evaluation or transportation planning (Siskos and Assimakopoulos, 1989; Hatzinakos et al., 1991; Demesouka et al., 2013). The presented work is one of the first research attempts in applying a multiple criteria preference disaggregation approach in the context of a systematic EPE process. It is, thus, the aim of this paper to outline the main principles of the original and fuzzy UTASTAR, and to demonstrate via an example application to a mills industry the use of fuzzy UTASTAR in the context of EPE.

Fuzzy UTASTAR, initially proposed by Patiniotakis et al. (2011), is an extension of the well-known UTASTAR method (Jacquet-Lagrèze and Siskos, 1982; Siskos and Yannacopoulos, 1985; Siskos et al., 2005) capable to handle both ordinary and fuzzy data, which allows its user to infer fuzzy value functions from a partial preorder of options, evaluated against multiple criteria. This property offers to the decision makers (DMs) much flexibility, which is necessary as it is well-known that the majority of the real-world decision problems include a high level of uncertainty that prevents the assignment of accurate evaluations (scores) to the available alternative options. In case of course that the evaluation data are crisp, the method behaves exactly as the original UTASTAR method (Patiniotakis et al., 2011).

2 Application and Results

2.1 Environmental performance indicators

To demonstrate the application of the fuzzy UTASTAR approach to EPE, a mill industry certified according to the ISO 9000 standard for quality management has been selected (Sbokou et al., 2014). The company produces a wide range of flour products for home use, professional, as well as for animal feeding. To this end it uses cereals like wheat, barley, corn, oats and rye as raw materials, as well as energy and water.

To conduct the EPE, data has been collected via the ISO 9000 quality manual, an Environmental Impact Study, several control lists, measurements and fieldwork within the industry's premises. Significant information has been also gathered through communication with the top management, as well as the directors of the different departments. This approach allowed the identification of the industry's environmental policy and goals, environmental aspects, environmental impacts, and the relevant national and European legislation (Sbokou et al., 2014).

The application of the a risk assessment approach reduced the initial set of 36 indicators to a final set including 17 indicators allocated to 5 different categories as summarized in Table 1. The first three indicators' categories concern environmental emissions, while the last three concern management-operational indicators.

It should be noted that the indicators, which are not included in the final set, may not be less useful or appropriate for the EPE process. The final set just reflects the current priorities and interests of the industry and should be regularly reviewed and updated in the future as part of the continuous improvement of the industry's EPE process.

2.2 Development and evaluation of scenarios

In order to apply fuzzy UTASTAR, a reference set should be developed including alternative scenarios involving different combinations of indicator values that can be evaluated and prioritized by the industry. For each indicator 3 performance levels were identified to reflect low, medium and high value. To further define the reference set for each indicator category, a scenarios development methodology was used, based in the design of statistical experiments taking into account a subset only of all possible combinations of indicator values.

Following the aforementioned rationale, reference sets were defined as follows: a) reference set including 4 scenarios for the indicators' category air emissions (includes 3 indicators); b) reference set including 7 scenarios for the indicators' category solid waste (includes 6 indicators); c) reference set including 3 scenarios for the indicators' category resources and energy (includes 2 indicators); d) reference set including 3 scenarios for the indicators' category environmental education and third parties (includes 2 indicators); and e) reference set including 5 scenarios for the indicators' category recycling and improvement actions (includes 4 indicators).

Table 1. The final set of indicators.

Category	Indicator	Units
Air emissions	Quantity of CO_2	tn of CO_2 / month
	Quantity of NOx	kg of NOx / month
	Quantity of SOx	kg of SOx / month
Solid waste	Quantity of production process biproducts	kg of bioproducts /day
	Quantity of waste from packing of raw and other materials	kg of packing materials / month
	Ash quantity	kg of ash / month
	Percentage of well-managed phosphine packing	% of used phosphine packing disposed via authorized bodies / month
	Percentage of well-managed used batteries	% of used batteries disposed via authorized bodies or returned to suppliers / month
	Percentage of well-managed used oils	% of used oils disposed via authorized bodies / month
Resources and energy	Average water consumption	m3 of water / month
	Noise levels at the production units and the borders of the industry facilities	dB
Environmental education and third parties	Number of proposals for the improvement of environmental performance	Number of proposals / year
	Number of complaints from the local community	Number of complaints / year
Recycling and improvement actions	Number of products or packings with clear environmental guidelines for use and disposal	% of products and packings with such guidelines
	Number of emergency exercises carried out	Number of emergency exercises carried out / total number of planned emergency exercises
	Time to respond to and complete corrective actions	Number of days for response and completion of corrective actions / year
	Cost allocated to improvement actions and environmental initiatives as part of the total budget	Environmental-related costs / total budget

2.3 Fuzzy UTASTAR results

Given the criteria and the reference sets defined for each environmental indicator category, the fuzzy UTASTART model is applied to provide (fuzzy) marginal and global value functions.

Table 2 summarizes the performance assessment of the industries' current condition using the previous value functions. More specifically, the first and the second columns list the considered dimensions and the indicators per dimension, respectively. The third column presents the current values of the indicators as measured/estimated by the industry, while the fourth column shows the value of the current indicator as estimated (via linear interpolation) using the value functions of calculated by Fuzzy UTASTAR. The last column presents the same results with the previous column, which are now normalized in the range [0, 1].

Table 2. Assessment of current industry performance based on fuzzy UTASTAR results.

Category	Indicator	Current value	Unweighted value	Normalized (weighted) value
Air emissions	Quantity of CO_2	35	0.080	0.667
	Quantity of NOx	75	0.029	0.674
	Quantity of SOx	160	0.452	0.540
	Overall value of air emissions		0.561	
Solid waste	Quantity of produced biproducts	3	0.300	0.806
	Quantity of waste from packing of raw and other materials	25	0.119	0.783
	Ash quantity	450	0.041	0.225
	Percentage of well-managed phosphine packing	100	0.100	1.000
	Percentage of well-managed used batteries	100	0.100	1.000
	Percentage of well-managed used oils	100	0.094	1.000
	Overall value of solid waste		0.754	
Resources and energy	Average water consumption	800	0.077	0.770
	Noise levels at the production units and the borders of the industry facilities	48	0.100	0.111
	Overall value of resources and energy		0.177	
Environmental education and third parties	Number of proposals for the improvement of environmental performance	1	0.083	0.332
	Number of complaints from the local community	1	0.750	1.000
	Overall value of environmental education and third parties		0.833	
Recycling and improvement actions	Number of products or packings with clear environmental guidelines for use and disposal	85	0.100	0.775
	Number of emergency exercises carried out	100	0.250	1.000
	Time to respond to and complete corrective actions	4	0.198	0.333
	Cost allocated to improvement actions and environmental initiatives as part of the total budget	2	0.120	0.444
	Overall value of recycling and improvement actions		0.668	

More specifically, the assessment results of Table 2 transform the current values of the selected indicators using the estimated value functions. For example, the industry currently emits 35 tn of CO2 per month and this corresponds to a weighted value (score) of 0.080. The sum of these weighted values provide an overall performance score for the EPE dimensions (e.g., 0.561 for air emissions, in a range of 0.000-1.000). Usually the performance score of the set of indicators is also presented in an unweighted form, in order to have clear view about potential improvement actions. For example, the weighted value of 0.080 of the quantity of CO2 corresponds to an unweighted value of 0.667. The latter is defined in [0, 1] and reveals the moderate performance of the industry in this particular indicator.

Figure 1 presents the overall EPE using the aggregated value of indicators within a specific category (fourth column of Table 2). This type of graph provides a general view of the industry's EPE. As shown, resources and energy is the environmental dimension with the lowest performance, while other dimensions may also require improvements (e.g., air emissions).

The previous findings provide a clear view of the strengths and weaknesses of the industry's EPE. Most importantly, it can identify the parts of environmental management that need improvement, as well as the level of effort that is required for this improvement. They are very useful as they can display in a simple and understandable manner to the top management the performance of the industry. They also allow for comparisons with past performances, as well as for the establishment of particular goals per indicator, per environmental dimension or globally.

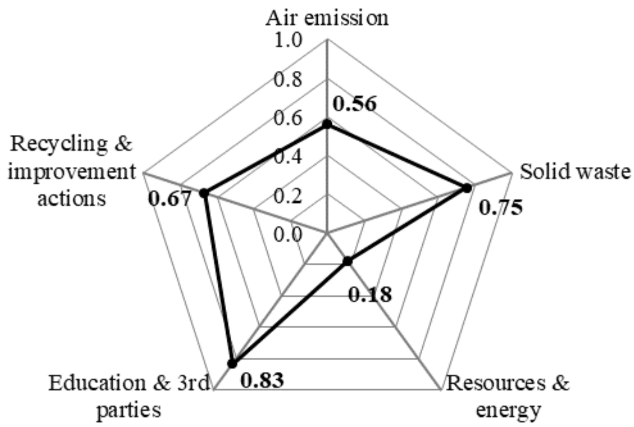

Fig. 1. Overall environmental performance evaluation per dimension.

3 Concluding Remarks

EPE is an important tool for the evaluation and the documentation of a successful environmental management system. The EPE is defined as a continuous internal process and a management tool that uses indicators in order to evaluate the environmental management system of a business organization and to compare past and present environmental performance. International standards ISO 14031-14032 describe the categories of performance indicators; however they do not determine a specific framework for the development and measurement of these indicators. The main aim of this study is to present an EPE methodology based on a fuzzy multicriteria analysis approach.

In particular, the Fuzzy UTASTAR method is applied in order to evaluate the environmental performance of a mill industry. Fuzzy UTASTAR, as presented herein, comprises a method that carries all the characteristics of the original method and at the same time can also handle fuzzy data. With fuzzy UTASTAR, the estimated value functions are also fuzzy, focusing mainly in taking into account the ambiguity and uncertainty, which are common characteristics in real-world problems and situations. Fuzzy UTASTAR is able to handle this vagueness assisting DMs in their difficult tasks, and at the same time easies the modelling of his/her preferences.

As far as EPE is concerned, the application presented herein showed that fuzzy UTASTAR is able to identify the weaknesses in relation to environmental issues, thus allowing organizations to align their improvement efforts and actions based on their environmental policy. It can also provide a clear view of the distance of the organization from its goals and targets. Conclusively fuzzy UTASTAR is an approach that can be adopted by organizations, irrespective of size and type of activity, and enable them to evaluate their environmental performance in an easy and straightforward manner.

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