Sustainability Enhancement through Environmental Impacts Evaluation

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Abstract. The work is aimed to propose an approach toward the evaluation of environmental impacts enhancing sustainability and the process of environmental assessment in an optic of sustainable development. A set of environmental aspects applicable to a firm activity to define the overall environmental impact are selected and processed through a fuzzy approach aimed to reduce subjective judgments. The procedure is based on a vectorial graph allowing to organize data and define a structured data analysis. An action research conducted in a genetic research center is conducted to evaluate the effectiveness of the proposed approach.

Keywords: Sustainability, Environmental impacts, Fuzzy techniques

1 Introduction

Environmental Impact Assessment (EIA) is an efficient method for preserving natural resources and protecting the environment. Therefore, most developed countries have introduced EIA into their regulations and the consequent approval of all projects [8]. An EIA can be a useful tool to promote the goals of sustainable development as the process includes assessments of the effects of a project development and includes local opinion and knowledge [15]. Too often in the past, development projects have taken place in developing countries without EIA studies or conscious efforts to predict and mitigate adverse environmental impacts [2]. Nowadays, the trend toward industrial sustainability is observed in many matters requiring a shift in managerial and methodological approaches [10]. Despite criticism, the influence on decision making still maintains its importance as a criterion of effectiveness of the EIA system because of its valuable attributes - quantifiability with descriptive statistics and understandability to involved parties [11].

The work presents a methodical approach to enhance sustainability and environmental assessment process. It selects a set of environmental aspects which can be applied to a firm activity, defining its overall environmental impact. This is done thorough a fuzzy approach aimed to reduce subjective judgments rising along multi criteria processes. The procedure is based on a vectorial graph allowing to organize data and define a structured data analysis.

The work is organized in five sections: after a literature review on sustainability, environmental management approaches and application fields of fuzzy techniques, the third section shows the methodical proposal for the sustainability environmental assessment, the fourth section describes the action research conducted in a genetic research center and its main results while the last section deals with conclusions.

2 Literature Review

-Sustainability and Environmental Management Systems

The term “sustainable development” was coined by the IUCŃs 1980 World Conservation Strategy stating that “for development to be sustainable it must take account of social and ecological factors, as well as economic ones” [12]. In this sense, environmental sustainability can be considered one of the three pillars of sustainable development, together with social and economic one [22]. White and Nobel [24] examined the strategic environmental assessment (SEA) sustainability relationship over the past decade, focusing in particular on the incorporation of sustainability in SEA while Apolloni and Savino [1] analyzed the motivations that can lead Small and Medium Enterprises to implement an Environmental Management System.

The progress of improving sustainability can be evaluated by a set of appropriate environmental sustainability indicators with reasonable target values [23]. Fischer and Gazzola [9] or Bond et al. [4] identified effective sustainability assessments involving procedural, substantive, transactive and normative elements. Manzini et al. [16] developed a model for assessing the environmental sustainability of energy projects not only integrating environmental sustainability indicators over the lifetime of the project but also taking into account the influenced area by the local energy project. Moldan et al. [17] pointed out the attention toward different approaches and types of indicators developed for the assessment of environmental sustainability to set targets and then “measuring” the distance to a target to get the appropriate information on the current state or trend. On the same line, Caniato et al. [7] developed a research aimed at identifying the drivers that push companies to adopt “green” practices, the different practices that can be used to improve environmental sustainability, and the environmental Key Performance Indicators (KPI) measured by fashion companies. Cai et al. [6] explored the role of information technology (IT) for energy and environmental sustainability for its crucial role in the energy consumption and environmental related issues while Petrini and Pozzebon [20] managed sustainability with the support of business intelligence.

-***Fuzzy approaches for environmental assessment***

Over the last years several approaches based on fuzzy logic have been developed to assess environmental impacts, indicating the potential of fuzzy logic in this field [19]. As an example, Peche and Rodriguez [19] presented a fuzzy procedure specifically developed to control and minimize the inconsistencies that arise from the available information on environmental impacts while Blanco et al. [3] developed an EIA computational application based on fuzzy logic, which takes into account either the quantitative or the qualitative assessments of each environmental impact. Similarly, Larimian et al. [14] proposed a model to achieve environmental sustainability using a fuzzy Analytic Hierarchy Process (AHP) to prioritize environmental factors. A fuzzy decision aid model for environmental performance assessment in waste recycling is developed by Nasiri and Huang [18] while Kaya and Kahraman [13] proposed an environmental impact assessment methodology based on an integrated fuzzy AHP–ELECTRE approach where weights of the assessment criteria are determined by a fuzzy AHP procedure. In general terms, applications of fuzzy techniques can also be found with reference to maintenance [21], [5] or economy [25].

3 Methodological proposal

A multi decision problem is featured by different and relevant aspects where multiple objectives can be involved. A new methodology has been proposed aimed to overcome the limits of common techniques in order to obtain a fair and objective evaluation of such goals. Fuzzy logic has been applied to a vectorial graph which represents a tool of simple applicability providing at the same time useful information in visual form. Such method allows the auditor to identify from a qualitative and quantitative point of view the most critical environmental aspect for the organization and together the industrial activities involved in such aspect.

As shown in Fig. 1, the graph is organized in two levels of nodes: the first level represents the firm activities which can be in [1,N] interval while the second one represents the environmental aspects in [1,M] interval. Eight environmental impacts has been selected: (i) fuel consumption, (ii) water consumption, (iii) power consumption, (iv) air pollution, (v) special wastes, (vi) smell, (vii) noise and (viii) dangerous materials.

Arches link the two levels of nodes indicating that a given activity generates an impact on one or more environmental aspects. In Fig. 1, the third activity generates impact over the fifth, sixth and eight environmental aspect. In addition, a four position vector can be associated to each arch indicating the (i) legislation compliance -LC, (ii) impact entity –IE on the basis of detectability, dangerousness and importance, (iii) control degree –CD according to type of control and reaction capability, and (iv) territorial sensitivity –TS considering territorial context and claims frequency: {LC, IE, CD, TS}.

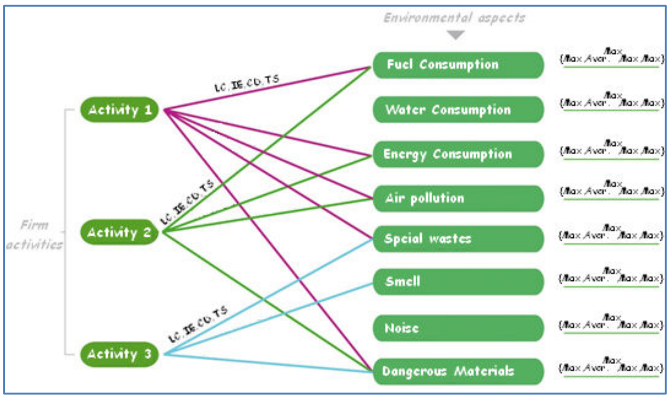

Fig. 1. Vectorial graph

As an example, Impact Entity is based on the following three parameters: (1) Consistency of the impact-C, (2) Dangerousness -D and (3) Degree of Detectability -DD. C assumes the following values according to some conditions related to consistency: 1 - negligible, 2 – low, 3 – medium, 4 – high. D is the dangerousness toward environment and health assuming values: 1 – no dangerousness, 2 – dangerous , 3 – very dangerous, 4 – extremely dangerous. Finally, DD can assume values 1 in case of immediate and simple detectability, 2 in case of detectability performed by proper instruments, 3 in case of detectability through bio-chemical analysis and 4 in case of impossible detectability. The value IE is obtained by the average of these three parameters.

The four position vector is filled for each activity and its corresponding environmental aspects; for this reason, to each second level node, i.e. the environmental impact, an impact matrix [nx4] can be associated according to the number of n (n<=N) activities linked to the environmental impact. The matrix is elaborated to obtain an overall vector referred to the environmental impact, i.e. {*max[LC]*, $average[IE]^{\max[IE]}$, *max[CD], max[TS]*}. Elevating to its maximum value the average of IE favors the accountability of dangerousness within the process of impact evaluation. LC, CD and TS are evaluated on a [1, 4] scale for IE a fuzzy set on a [1, 4^4] scale is used.

The final evaluation of the environmental impact is performed considering the overall vector. Values of the first, third and last column are compared to a [1, 4] scale indicating possible corrective actions to be planned and the respective timing: 1) Not necessary actions, 2) Long/Medium term actions, 3) Short term actions, 4) Urgent actions. On the other hand, the second value of the overall vector is evaluated according to a triangular or trapezoidal fuzzy function by the use of Matlab, a mathematical software. A flow diagram summarizing the methodology is shown in Fig. 2.

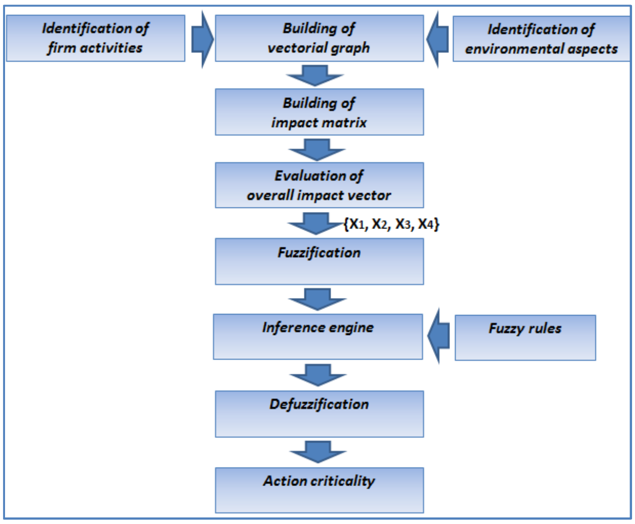

Fig. 2. Methodology flow diagram

According to the selected environmental aspects and the firm activities to be investigated, the corresponding vectorial graph is built through whom it is possible to obtain the impact matrix. Values of relative overall impact vector are processed by a classical fuzzy process made of a fuzzyfication step, an inference engine according to fuzzy rules and a de-fuzzyfication step. Such process allows to define the criticality of the selected activity with respect to the environmental aspects.

4 Application case and results

Proposed methodology has been validated on field in a genetic research center. For simplicity and according to environmental assessment, in the present work the analysis has been focused on two firm activities, i.e. (1) animal breeding and (2) laboratories, and six environemenatal impacts, as shown in Fig. 3.

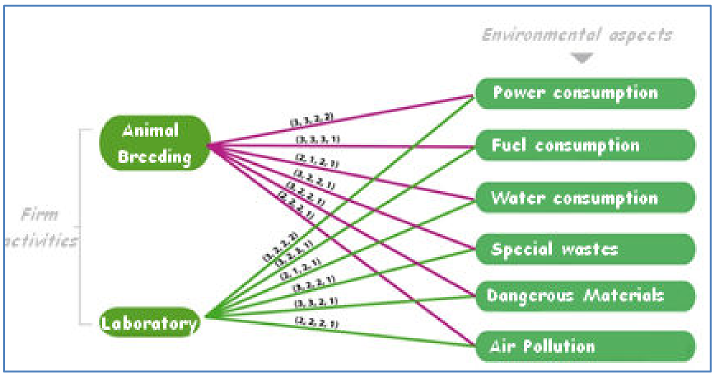

Fig. 3. Vectorial graph – Application case

Each activity has been related to the environment aspect filling the respective impact vector to define values LC, IE CD and TS. The vector has been processed by a fuzzy analysis through the use of fuzzy rules and functions, as shown in Fig. 4.

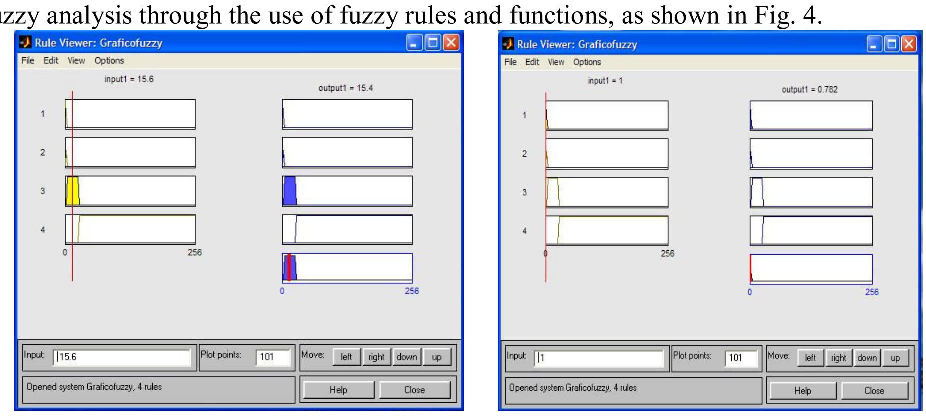

Fig. 4. Fuzzy rules implemented thorough a mathematical solver

Values LC, CD and TS are compared to a [1, 4] scale as stated in the previous section. Concerning fuzzy value IE, it has been decided to interpret the outcomes as follows:

- $IE \in [0,2]$: no necessary interventions;
- $IE \in]2,4]$: long/medium term interventions are necessary;
- $IE \in]4,27]$: short term interventions are necessary;
- $IE \in]27,256]$: urgent interventions are necessary.

Values have been set through a tuning performed in accordance to firm management on the basis of the possible outcomes. More in details, short term and urgent interventions have been preferred defining not balanced value intervals for IE.

For the specific case study, the analysis of the de-fuzzyfied overall impact vector allowed to state the following:

- Legislation compliance necessitates of short term interventions for power and fuel consumption, special wastes and dangerous materials while of long/medium term interventions for water consumption and air pollution;
- Impact Entity necessitates of short term interventions for power and fuel consumption, dangerous materials, special wastes and air pollution while no interventions are needed for water consumption;
- Control Degree necessitates of short term interventions for fuel consumption and of long/medium term interventions for power and water consumption, special wastes, dangerous materials and air pollution;
- Territorial Sensitivity necessitates of long/medium interventions for power consumption while no interventions are needed for the remaining environmental aspects.

5 Conclusions

The present work defines a methodological proposal for the evaluation of environmental impacts with the objective to improve firm sustainability. Such goal is achieved with reference to resource usage and pollution reduction in order to prevent environmental impacts such usage of dangerous material or waste production.

A set of environmental aspects have been selected which can be taken as a reference while conducting an environmental assessment; by the use of such aspects it is possible to define the impacts that a given firm activity generates. A method matching the activities and the relative environmental impacts is proposed through a vectorial graph providing useful information about the entity of each impact. A further analysis of these multiple impacts provides a value indicating the overall environmental impact of each activity. To overcome subjectivity in such multi criteria process, a fuzzy technique has been proposed and developed through the use of a mathematical solver.

The methodology has been validated in a real test case considering a genetic research center and focusing on two main activities and six environmental impacts. The analysis has allowed to define intervention area of the firm with respect to some lacks in terms of environmental aspects which the procedure has allowed to highlight. Together with intervention area, the methodology has provided a timing of corrective actions to be performed to front weak aspects emerged during the analysis. The support provided by fuzzy set theory application allows to reduce and overcome uncertainties and subjectivity in the values assignment procedure which can be found in other models.

In general terms, such methodology is well suited to be used in a wider environmental management system where in accordance to actual regulations a certification process is sometimes necessary. It can provide a strong support to a criticality analysis of environmental aspects, focusing on intervention area and defining corrective actions ad respective timing through a fair and objective analysis.

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