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EXTRA – FINANCIAL MULTIPLE CRITERIA OPTIMIZATION MODEL FOR ASSESSING THE ECOLOGIC – ECONOMIC EFFICIENCY OF AN ENVIRONMENT POLICY

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Abstract: The most common decision methods express the efficiency criteria in terms of money expenditure efficiency. Money seem to be the unique manner of measuring economy, society, ecology, science processes, but sometimes they generate concepts of efficiency coming into conflict with the most precious values of the mankind. We present a manner of deducing *an ecologic-economical effectiveness index of an environmental policy* which provides the decision maker with an inner characterization of the environmental policy, depending only on the results of the policy itself. The paper is supported by the Romanian Education and Research Ministry, within the Research Project ID-1239/2007. This index was tested as a decision method in choosing the policy of reducing the temperature within a company in Arad County during the summer time.

1. Introduction and Basic Concepts for solving problem

Many ethical issues appear in the process of selecting an environmental policy to protect the employees within a company and to keep the work productivity at high level, also trying to minimise the costs. The need of economic-ecologic efficiency of an environmental policy of a company is often mentioned both in technical and in scientific literature. But a method of assessing this kind of efficiency is never described. There are specific extra-economic possibilities of describing the efficiency of an ecology activity, as, for example, measuring the concentration of certain substances in the soil, air, water, food, etc. But a general tool, as an efficiency index to characterize an environment policy is totally absent. The relationship between industry and environment should receive considerable attention from two points of view: within the organization and between the organization and the society and nature. An ecological behaviour of the organization in relation both with its employees and with the society should be normal at the end of the first decade of the 21st century, when so many changes in the nature are of great mankind concern. So, a method of assessing the efficiency of the environment policy is necessary. Our aim is to study few possibilities of solving this problem and to develop an economic-ecologic effectiveness index for this purpose. The research resulting in this paper is part of the Research Project ID-1239/2007, funded by the Romanian Education and Research Ministry.

The multiple criteria optimization tools are used to derive an efficiency characterization of an environment policy. First, let us recall few basic concepts that are used in this paper. Let X be a nonempty set and let $f = (f_1, f_2, \ldots, f_n): X \to \mathbf{R}^n$.

Definition 1.1. *A point $a \in X$ is called a min-efficient point of f on X if there is no $x \in X$ such that*

$$f_i(x) \le f_i(a),\ i \in \{1, 2, \ldots, n\},\ \text{and } \sum_{j=1}^{n} f_j(x) < \sum_{j=1}^{n} f_j(a).$$

In order to solve a multiple criteria problem denoted by (*PE*),

$$(PE): \qquad (f_1, f_2, \ldots, f_n) \to \underset{x \in A \subseteq X}{\text{v} - \min}$$

we use the weight method, obtaining a unique synthesis function. The main result of Galperin [3] is fundamental in elaborating the solution of problem (*PE*):

Theorem 1.2. *If $\lambda_1>0$, $\lambda_2>0$, ..., $\lambda_n>0$ are n given real numbers, then every minimum point of the function $F: X \to \mathbf{R}$, defined by*

$$F(x) = \sum_{j=1}^{n} \lambda_j f_j(x)$$

for every $x \in X$, is a min-efficient point of the vectorial function f on X.

An algorithm for finding the min-efficient points of a vectorial function is published in the second part of [2].

2. The characterization of an environmental policy

There are many domains that use efficiency indexes to assess various types of activities, economic processes. For example, in the energy domain there are more types of efficiency index, both in terms of costs and in terms of effects, depending on the aim of the researcher (see [1], [6], [7]). The relationship between trade and environmental conditions is very important whenever countries are in the process of negotiating trade agreements. So, an environmental efficiency index for a sample of high income and low and middle income countries was developed [7] allowing to examine the role of trade on the changes in environmental efficiency.

The idea of an efficiency of a legislation system was recently published ([8]). We treat the problem of keeping a healthy environment by similar methods to farmaco-economics, from mathematical point of view (see [2], [4]), looking to an environmental policy like to a vaccine to prevent a disease [5]. The multiple criteria programming is used in order to make the best choice.

2.1. Problem formulation

The aim of this section is to obtain a practical and useful possibility of characterizing an environmental policy, using multiple criteria programming. We take into account more points of view in the further research: cost, effectiveness, side effects and their seriousness, etc.

Two similar environments are necessary for testing a policy. One environment is submitted to the environmental policy, while the other one is not. One can replace these two environments by the same one living first without the environment policy and after it, changing the environment according to the environment policy. We take into account more different aspects referring to the concentration of various substances affecting the environment's health.

First, let us deal with the environment measured behaviour. It is known that the normal concentration of substance *k* in water (air, soil), for $k \in \{1, 2, \ldots, n\}$ is $p_{Nk}\%$.

After a known period of time,

- out the environment non-submitted to the environment policy, p_k% is the concentration of substance k in water (air, soil), for $k \in \{1, 2, \ldots, n\}$;
- out the environment submitted to the environment policy, p_{Ek}% is the concentration of substance k in water (air, soil), for $k \in \{1, 2, \ldots, n\}$.

The following costs are known:

- c_k the cost of the pollution by increasing the concentration of substance k if the environment policy is not applied;
- c_E the total cost of applying the environment policy;
- c_{Rk} the cost of the total recovery of the normal concentration of substance k if the environment policy is applied;
- c_A the cost of treating the negative reactions or side effects if the environment policy is applied.

The main purpose is to elaborate a method of choosing an environmental policy such as to bring each substance in water, air, soil as close to the normal level as possible. The ecologic-economic efficiency of the environment policy should be studied in these conditions. For this purpose, a mathematical model is attached to this problem, in terms of a multiple criteria programming problem in variables *0* and *1.* These values are meant to express the preference for a type of action, meaning that two binary variables, x_1 and x_2 are introduced, having the following significance:

- $x_1 = 1$ means that the environment policy is used;
- $x_1 = 0$ means that the environment policy is not used;
- $x_2 = 1$ means that no environment policy is preferred;
- $x_2 = 0$ means that the environment policy is preferred.

Of course, $x_1 + x_2 = 1$, since an environment policy may be only accepted or rejected. The objective functions are $f_1: \{0,1\} \times \{0,1\} \to \mathbf{R}$, $f_2: \{0,1\} \times \{0,1\} \to \mathbf{R}$ and $f_3: \{0,1\} \times \{0,1\} \to \mathbf{R}$, defined, for every $(x_1, x_2) \in \{0,1\} \times \{0,1\}$ by:

$$f_k(x_1, x_2) = \left(1 - \frac{p_{Ek}}{p_{Nk}}\right)x_1 + \left(1 - \frac{p_k}{p_{Nk}}\right)x_2, \text{ for } k \in \{1, 2, \ldots, n\},$$

$$f_{n+1}(x_1, x_2) = x_1 + \frac{\alpha}{\alpha_E} x_2,$$

where $\alpha = \sum_{k=1}^{n} c_k$ and $\alpha_E = c_E + c_A + \sum_{k=1}^{n} c_{Rk}$ .Then, the solution comes from finding the min-efficient points of the following vectorial programming problem, denoted by (*PE*):

$$(PE) \quad \left(\frac{p_{E1}}{p_{N1}}x_1 + \frac{p_1}{p_{N1}}x_2, \frac{p_{E2}}{p_{N2}}x_1 + \frac{p_2}{p_{N2}}x_2, \ldots, \frac{p_{En}}{p_{Nn}}x_1 + \frac{p_n}{p_{Nn}}x_2, x_1 + \frac{\alpha}{\alpha_E}x_2\right) \to \text{v-min}$$

when $x_1 + x_2 = 1$, $(x_1, x_2) \in \{0,1\} \times \{0,1\}$.

2.3 Solution to problem (*PE*)

In order to solve problem (*PE*), we use the pounds $\lambda_k > 0$, for $k \in \{1, 2, \ldots, n, n+1\}$, to introduce the synthesis function $F: \{0, 1\} \times \{0, 1\} \to \mathbf{R}$, getting

$$F(x_1,x_2) = \sum_{k=1}^{n+1} \lambda_k f_k(x_1,x_2).$$

With this function, problem (*PE*) turns into the following problem (*P*):

$$F(x_1,x_2) = \sum_{k=1}^{n} \lambda_k \left(-\frac{p_{Ek}}{p_{Nk}} x_1 - \frac{p_k}{p_{Nk}} x_2 \right) + \lambda_{n+1} \left(x_1 + \frac{\alpha}{\alpha_E} x_2 \right) \to min,$$

when $x_1 + x_2 = 1$, $(x_1, x_2) \in \{0,1\} \times \{0,1\}$. By elementary calculus one gets

$$F(0,1) = \sum_{k=1}^{n} \lambda_k \frac{p_k}{p_{Nk}} + \lambda_{n+1} \frac{\alpha}{\alpha_E},$$

$$F(1,0) = \sum_{k=1}^{n} \lambda_k \left(-\frac{p_{Ek}}{p_{Nk}} \right) + \lambda_{n+1}$$

and, as consequence,

$$F(1,0) - F(0,1) = \sum_{k=1}^{n} \lambda_k \frac{p_{Ek} - p_k}{p_{Nk}} + \lambda_{n+1} \left(1 - \frac{\alpha}{\alpha_E} \right).$$

If $F(1,0) - F(0,1) \leq 0$ then one can decide that the environmental policy is profitable. Also, an environmental policy is better than another one if its $F(1,0) - F(0,1)$ is the lowest one (i. e. its absolute value is the greatest one). This result is the reason of using the difference $F(1,0) - F(0,1)$ as a method of making the decision, when the choice of an environmental policy is under debate.

2.4. The ecologic-economical effectiveness index

In this subsection we investigate the properties of the difference $F(1,0) - F(0,1)$ and the manner in which it is able to turn into a decision making tool in the process of choosing an environmental policy.

Definition 2.1. *The ecologic-economical effectiveness index of an environmental policy is the number*

$$EEf = \sum_{k=1}^{n} \lambda_k \frac{p_{Ek} - p_k}{p_{Nk}} + \lambda_{n+1} \left(1 - \frac{\alpha}{\alpha_E} \right).$$

As one can remark, this index provides an inner characterization of the effect of an environmental policy on the nature under treatment, since it does not depend only on costs, taking into account the effects of the policy on the environment.

The monotony properties of this index are:

- *EEf* decreases when the environmental policy brings the substances in nature to their normal level;
- *EEf* decreases when the side effects under the environmental policy produces lower costs than the complications in absence of an environmental policy.

As consequence, one can say that *an environmental policy is more efficient than another one if it has a lower negative EEf.*

On another hand, it depends on the social or moral system of values of the decision makers: the pounds λ_k are chosen according to the importance given to each criterion f_k within a company or the whole society.

Example 2.2. This index was tested as a decision method in choosing the policy of reducing the temperature within a company in Arad County during the summer time. The increase of the temperature at more than 35° C had severe consequences not only by drastically decreasing the work efficiency of the employees but also on their momentary health condition. All the effects of the increase of the temperature on employees will be referred in what follows as disease. Therefore, a policy of reducing the temperature within the company was urgently applied, choosing it by some rules of thumbs. The unit of the company, we have been allowed to study, has 2540 employees, having no healthy issues in normal conditions (average temperature of 24° C). The total cost of the complete recovery per one season is 6000 €, the total cost of treating the complications is 10000 € and the total cost of treating the side effects of the environmental policy is 15000 € for the entire personnel per season. Before taking action for reducing the temperature, the behaviour of the company employees working within the unit under investigation was recorded as follows: p_D = 0, p_N = 15%, p_C = 80%, p_R = 5%. Therefore, α_N = 433.1. Three solutions to reduce the temperature were presented to the company. The estimated consequences of each policy are presented in the following table.

Project	Reduced temperature	Total cost (€)	P_{EN} %	P_{ER} %	P_{ED} %	P_{EA} %	α_E
1	28° C	45600	80	10	0	5	1861.1
2	30° C	250000	70	15	0	7	9952.75
3	22° C	490000	100	0	0	0	19291.34

Taking the pounds $\lambda_1 = \lambda_2 = 2$ and $\lambda_3 = 1$ (according to the opinion of company's staff) and computing the ecologic-economical effectiveness index of each environmental policy, we got

$$EEf(\text{project1}) = -129.24,$$

$$EEf(\text{project2}) = -109.04,$$

$$EEf(\text{project3}) = -169.02.$$

It shows that Project 3, which reduces the temperature at 22° C, is the most efficient from the point of view of the employees' behaviour at their workplace.

According to our opinion, the use of an index of this kind instead of the known ones, referring mainly to costs and benefits, when an environment strategy is discussed, is an ethical option. As one can see, in this method of approaching the problem, the costs may be present as auxiliary parameters, with secondary impact on the decision making process.

References

[1] T. Barker, P. Ekins, N. Strachan, *Energy-Economy-Engineering-Environment: An E4 Representation of the UK Energy System*, UK Energy Research Centre, on line [http://www.ukerc.ac.uk];

[2] G. Cristescu, Liana Lupşa, *Non-Connected Convexities and Applications,* Kluwer Academic Publishers, Dordrecht / Boston / London, 2002;

[3] E. A. Galperin, *Nonscalarized Multiobjective Global Optimization,* J. O. T. A. 75, 1(1992), 69-85;

[4] Luciana Lupşa, *Construction of a Medico-Economic Effectiveness Index which Characterizes a Vaccine*, Séminaire de la Théorie de la Meilleure Approximation, Convexité et Optimisation (editor E. Popoviciu), Srima, Cluj-Napoca, 2001, 61-65;

[5] L. Neamțiu, *Applications of the Numerical Analysis, Optimisation and Informatics in Medecine* (in Romanian), Ph.D. Thesis, "Babeş-Bolyai" University of Cluj-Napoca, Faculty of Mathematics and Computer Sciences, Cluj-Napoca, 2007;

[6] H-P. Siderius, R. Harrison, *An Energy Efficiency Index for TVs, In 'Energy Efficiency in Household Appliences and Lighting'* (editors Bertoldi, Ricci, de Almeida), Springer Verlag, Berlin, 2001, 267-277;

[7] F. Taskin, O. Zaim, *The role of international trade on environmental efficiency: a DEA approach,* Economic Modelling, 18, 1(2001), 1-17;

[8] M. Varsavsky, *Legislation Efficiency Index,* (2005) on line [http://english.martinvarsavski.net/general/legislation-efficiency-index.html], posted May 29 2006.