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THE MULTICRITERIA METHOD FOR ENVIRONMENTALLY ORIENTED BUSINESS DECISION-MAKING

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Abstract: Stimulated by the expressed managers' need for some completed methods for environmental management in enterprises, we present the method for environmentally oriented business decision-making. It is based on simulations where optimization models of business processes are used as scenarios. The possibilities for an integrated approach to environmental protection are introduced and – decomposed according to the type of the considered element by using zero-one variables – included in the optimization models. The method is completed for multicriteria decision-making where in the simulations obtained optimal values are included. In a real-life case where the Analytic Hierarchy Process technique is used to evaluate environmentally oriented business processes, special attention is given to criteria and weights: we consider preferences and survey findings on the environmental impact of business processes in the enterprise, survey findings on environmental management in the processing industry, and eco-balances.

Keywords: Analytic Hierarchy Process, environmental management, linear mixed integer optimization model, multicriteria decision-making method, simulation.

1. INTRODUCTION

The results of our research on environmentally oriented business decision-making performed in 79 enterprises in the Slovene processing industry during November and December 2001; show that 43 % of the enterprises in the sample use the tools and methodology for environmental management in business decision-making. A great stimulus for our research work on environmentally oriented business decision-making is the firm belief of 74 % of the sample enterprises that environmental management helps enterprises to achieve business success. Moreover, 87 % of the sample enterprises expressed the need to use the completed basic tools and methodologies for environmental management.

Stimulated by the expressed managers' need for some completed tools and methodologies for environmental management in the Slovene processing industry, we present the method for the evaluation of environmentally oriented business processes. First, we briefly describe the basic method for environmentally oriented business decision-making. It is based on simulations where linear and linear mixed integer optimization models of total business processes are used as scenarios [6]. The possibilities for an integrated approach to environmental protection are introduced [7] and - decomposed according to the type of the considered element by using zero-one variables - included in the optimization models [5].

As economic and environmental goals may conflict in a short term (see, e. g. [3]), the decision makers should consider multicriteria decision-making methods. Therefore, the described method is completed for multicriteria decision-making where both quantitative and qualitative criteria are considered when evaluating environmentally oriented business alternatives. Using this method, we perform simulations for m alternatives

$$A=\{A_1, A_2, \ldots, A_m\},$$

where different environmentally oriented business decisions are included in the business process. Thus we obtain the optimal values that are included as the quantitative attributes' values, e.g. for the k-th attribute

$$h_{k_1}*, h_{k_2}*, \ldots, h_{k_m}*.$$

Besides quantitative criteria, qualitative criteria are taken into consideration when structuring a problem. It is not necessary that those business criteria are only quantitative or that environmental criteria are only qualitative factors. In a hierarchy, criteria can be structured in more levels so that lower levels specify sets of sub-criteria related to the criteria of the higher level. We obtain the attributes

$$H_1, H_2, \ldots, H_n.$$

The Analytic Hierarchy Process (AHP) technique (for fundamentals and exposition see, e.g. [9], [11], [12], [13]) with the appropriate computer program Expert Choice [8] is used to evaluate environmentally oriented business alternatives.

With pairwise comparisons of the attributes' importance and alternatives' preferences by the verbal, graphical and numerical mode the AHP provides the user-friendly consideration of the quantitative as well as the qualitative dimension of business processes: weights or priorities are not arbitrarily assigned, but are derived from judgments. The mathematical foundations of the AHP enable that the subjective judgments about the attributes' importance and alternatives' preferences are processed into objective final values. (For a detailed explanation of the objective mathematics that is provided by the AHP, see e.g. [11], [12], [13]).

This way of making decisions is based on the principle of constructing hierarchies, the principle of establishing priorities, and the principle of logical consistency. When verifying its applicability for the evaluation of environmentally oriented business processes in order to recognize the most acceptable one, we concluded that the technique should involve the following steps:

1. Problem definition
2. Problem structuring/building a model
3. Establishing priorities (on importance and preferences)
4. Synthesis to obtain the final alternative values
5. Sensitivity analysis and verification

1. When the problem arises, we should describe it accurately. We should define criteria and alternatives.
2. In the AHP we structure a complex situation in a hierarchical model. For each problem it consists of goal (in our case the evaluation of environmentally oriented business alternatives), criteria, very often some levels of sub-criteria, and alternatives (in our case business processes). In a hierarchy, criteria can be structured in more levels so that lower levels specify sets of sub-criteria related to the criteria of the higher level.
3. We have to establish the criteria importance in order to define the criteria weights. This step involves the judgments about the alternatives' preferences and the calculation of the alternatives' values with respect to each criterion on the lowest level as well. One of the major advantages of the AHP is the use of pairwise comparisons to derive accurate ratio scale priorities, instead of using traditional approaches of assigning weights. This process compares the relative importance of two criteria or the preference of two alternatives with respect to another element on the level above. In literature (see, e.g. [9]) the numerical and verbal scales for the intensities of judgments as they are used in the AHP are explained.

   When making pairwise comparisons between the importance of sub-criteria with respect to the criterion on the higher level, even experts are often inconsistent. The main reason is that they are not aware of the relationships among different criteria, taken into account for the evaluation of environmentally oriented business processes. With the (in)consistency ratio (see, e.g. [9]), calculated after entering the intensities with one of the appropriate computer programs, experts and managers can be warned that their understanding of the criteria importance is not good enough. In the case that this (in) consistency measure is greater than 0.1, they can conclude that the importance, assessed to the considered criterion, is over- or undervalued. Considering the intensities of other criteria importance, they can calculate the acceptable intensity.
4. In synthesis the additive model is used where the reciprocal preferential independence of criteria is assumed [14]. The synthesis is the process of changing the local priorities of the alternatives using the global priorities of their parent criteria. These are summarized at the model's last level for each alternative and thus the final values (overall priorities) of the business processes are obtained. Two ways or modes of synthesis are the distributive mode and the ideal mode. As we want to recognize the most acceptable environmentally oriented business process, we have to apply the ideal mode [12]: for each criterion, the local priorities of the alternatives are divided by the largest value among them [12]. When we want to evaluate all environmentally oriented business processes that are included in the model as

alternatives (e.g. in order to perform more of them), we would choose the distributive mode.
In the evaluation of environmentally oriented businesses processes the criteria are measured on different scales. The process of prioritization (expressing the importance or preference) solves the problem of having to deal with different types of scales, by interpreting their significance to the users' values. A weighting and adding process is used to obtain overall priorities (final values) for the alternatives (for details see, e.g. [11], [12], [13]).

5. Sensitivity analysis is used to investigate the sensitivity of the business processes' evaluation to changes in the criteria weights. It can be performed from the goal or from other criteria in the model.

The completed method for the evaluation of environmentally oriented business processes is presented with a practical case from the Slovene enterprise "Termoplast Bistrica ob Dravi". We briefly describe environmentally oriented business alternatives together with the corresponding optimal values, obtained by the method for environmentally oriented business decision-making. Special attention is given to the criteria determination, the assessment of the criteria importance and to the criteria weights and the alternatives' data. For these purposes we use the results of two surveys:

- on environmentally oriented business decision-making that we performed in 79 enterprises of the Slovene processing industry during November and December 2001 (Research 1),
- on the impact of the business process with polypropylene and polystyrene materials on the environment that we performed in the enterprise Termoplast in 2002 (Research 2).

Eco-points, obtained by the method of ecological scarcity in eco-balances [1], were also taken into consideration.

Finally, the applicability of the presented method for the evaluation of environmentally oriented business processes is discussed. Some developmental tendencies and further application possibilities are introduced as well.

2. THE BASIC METHOD

The basic method for environmentally oriented business decision-making includes the preparation of business decisions about some fields of environmental assessment and integrated environmental protection and improvement, so that business results of enterprises are increased and environmental performance is improved.

Beinat [2] emphasizes that due to the intrinsic complexity of environmental systems and the lack of information for the decisions, the integration of decomposed and holistic strategies is needed when approaching to environmental problems. We concluded that optimization of the total multiphase business process is needed to support decomposed and holistic decision-making. Further, to support environmentally oriented business decision-making, a general optimization model of the multiphase business process can be used as a scenario in the business process simulations.

2.1. Optimization model

The model is constructed for a multiphase business process where production elements of the business process and semi-products are processed into final products [10]. It is completed for environmentally oriented business decision-making [5]. For each relevant element a material balance constraint is needed:

$$e_i = \sum_{j \in R_i} r_{ij}(x_j) + y_i - \sum_{j \in Q_i} q_{ij}(x_j) - z_i \geq 0 \text{ , } i \in E. \tag{1}$$

Market limits and capacities of production means give rise to market constraints:

$$d_i \leq z_i \leq D_i \text{ , for some } i, \tag{2}$$

$$b_i \leq y_i \leq B_i \text{ , for some } i. \tag{3}$$

Limited financial sources for environmental purposes may give rise to budget constraint:

$$\sum_l \kappa_l \lambda_l \leq K \text{ .} \tag{4}$$

With the objective function the contribution is expressed; the objective is maximum:

$$\max \left(\sum_{i \in Z} p_i(z_i) - \sum_{i \in Y} s_i(y_i) - \sum_j v_j(x_j) \right). \tag{5}$$

When the contribution is decreased by progressive fixed costs, the following objective function is obtained:

$$\max \left(\sum_{i \in Z} p_i(z_i) - \sum_{i \in Y} s_i(y_i) - \sum_j v_j(x_j) - \sum_{i \in Z} g_i(z_i) - \sum_{i \in Y} c_i(y_i) \right) \tag{6}$$

When functions $p_i(z_i)$, $s_i(y_i)$, $v_j(x_j)$, $r_{ij}(x_j)$ and $q_{ij}(x_j)$ are linear, the model with the objective function (5) and the constraints (1) – (4) can be written as a linear optimization model. When instead of (5) the objective function (6) is used where with the sum $\sum_{i \in Z} g_i(z_i) + \sum_{i \in Y} c_i(y_i)$ progressive fixed costs are expressed and functions $p_i(z_i)$, $s_i(y_i)$, $v_j(x_j)$, $r_{ij}(x_j)$ and $q_{ij}(x_j)$ are piecewise linear, we can obtain the linear mixed integer optimization model. When $p_i(z_i)$ is a concave piecewise linear function and $s_i(y_i)$ is a convex piecewise linear function, we can use the following substitutions:

$$z_i = \sum_f z_{if} \text{ ,}$$

$$y_i = \sum_h y_{ih} \text{ ,}$$

where z_{if} is the quantity of the i-th element that is sold to the f-th customer and y_{ih} is the purchased quantity of the i-th element in the h-th source (see, e.g. [5], [10]). The constraints (2) and (3) can be substituted by

$$d_{if} \leq z_{if} \leq D_{if}\,, \quad \text{for some } i,\ f,$$

$$b_{ih} \leq y_{ih} \leq B_{ih}\,, \quad \text{for some } i,\ h,$$

where d_{if} is the minimum quantity of the *i*-th element that has to be sold to the *f*-th customer and D_{if} is the maximum quantity of the *i*-th element that can be sold to the *f*-th customer, whereas b_{ih} is the minimum quantity of the *i*-th element that has to be purchased in the *h*-th source and B_{ih} is the maximum quantity of the *i*-th element that can be purchased in the *h*-th source. When $r_{ij}(x_j)$ is a concave function and $q_{ij}(x_j)$ is a convex function, we can use the following substitution:

$$x_j = \sum_{\iota} x_{j\iota}\,,$$

where ι is the index of the performance mode of the *j*-th production activity. In the literature (see, e.g. [10]), some other conditions for successful application of the linear model to business optimization are described.

The description of the symbols is as follows:

Z – index set of relevant elements with customers outside business process;
Y – index set of relevant elements with sources outside business process;
E – index set of relevant elements;
R_i – index set of production activities producing the *i*-th element;
Q_i – index set of production activities processing the *i*-th element;
z_i – unknown quantity of the *i*-th element that is sold or disposed of;
y_i – unknown purchased quantity of the *i*-th element;
x_j – unknown quantity of the *j*-th production activity;
$p_i(z_i)$: $\Re \to \Re$ – income from the sale of the *i*-th element reduced by the variable selling cost or variable cost caused by the disposal of the *i*-th element, expressed as a function of unknown quantity of the *i*-th element that is sold or disposed of;
$g_i(z_i)$: $\Re \to \Re$ – progressive fixed costs due to the sale or disposal of the *i*-th element, expressed as a function of unknown quantity of the *i*-th element that is sold or disposed of;
$s_i(y_i)$: $\Re \to \Re$ – purchasing costs or prime variable cost due to the consumption of the *i*-th element, expressed as a function of unknown purchased quantity of the *i*-th element;
$c_i(y_i)$: $\Re \to \Re$ – progressive fixed costs due to the purchase of the *i*-th element, expressed as a function of unknown purchased quantity of the *i*-th element;
$v_j(x_j)$: $\Re \to \Re$ – variable costs of the *j*-th production activity due to the consumption of irrelevant elements, expressed as a function of unknown quantity of the *j*-th production activity;
e_i – unallocated quantity of the *i*-th element;
$r_{ij}(x_j)$: $\Re \to \Re$ – quantity of the *i*-th element produced by the *j*-th production activity, expressed as a function of unknown quantity of the *j*-th production activity;

$q_{ij}(x_j)$: $\Re \rightarrow \Re$ – quantity of the i-th element processed by the j-th production activity, expressed as a function of unknown quantity of the j-th production activity;
d_i – minimum quantity of the i-th element that has to be sold;
D_i – maximum quantity of the i-th element that can be sold;
b_i – minimum quantity of the i-th element that has to be purchased;
B_i – maximum quantity of the i-th element that can be purchased;
λ_l – zero-one variable of the l-th investment; its value is 1 when it is optimal to invest into the l-th investment project, otherwise is 0;
κ_l – the amount of capital needed for the l-th investment;
K – maximum available capital for all investments.

2.2. The possibilities of environmental protection in the optimization model

We included the possibilities for an integrated approach to environmental protection in the processing industry in the optimization model of the multiphase business process. By $\sum_{i \in Z} p_i(z_i)$, the income from the sale of primary and environmentally friendly products, semi-products as well as waste is expressed. This income is decreased by the costs of the waste disposal and the variable market cost of marketing activities. In the enterprises with proactive environmental strategy we consider not only obligatory costs of the waste disposal, caused by environmental laws, but also non-obligatory ones that are caused by the initiation of clean technologies and the development of the markets for environmentally friendly products. Progressive fixed costs of the sale of the environmentally friendly final products and semi-products as well as the waste sale and disposal are expressed by $\sum_{i \in Z} g_i(z_i)$. For example, the promotional cost of green promotions can be expressed by this sum. Variable costs that are caused by the purchase of relevant elements are expressed by $\sum_{i \in Y} s_i(y_i)$. Progressive fixed costs of the purchase of environmentally friendly elements of the business process and semi-products are expressed by $\sum_{i \in Y} c_i(y_i)$. Other variable costs of production activities due to the consumption of irrelevant elements are expressed by $\sum_{j} v_j(x_j)$.

We can also decompose the possibilities of integrated environmental protection in the multiphase business process, i.e. substitution of raw materials, suppliers, semi-products and final products as well as recycling processes and technology improvements, according to the type of the considered element. Using zero-one variables, we can write the constraints for the sold quantity of the primary product that is conditional on the minimum sold quantity of the environmentally friendly product; similar constraints can be constructed for purchasing activities. Further, we can write the claim for the whole source substitution by using zero-one variables when considering environmental quality of the element at the source's index; we can consider the maximum quantity of the waste disposal, the maximum quantity of the environmentally friendly product or semi-product that can be sold when the promotion is realized, the maximum quantity of the environmentally friendly production element that can be purchased when marketing research is realized, and the increase of the machine capacities due to investments [5]. Let us introduce some of these possibilities.

- When the i-th element is waste, it can be sold or disposed of. Moreover, it can be purchased from outside sources or recycled. When all of the produced and purchased quantity of waste must be recycled, sold or disposed of, the constraint (1) is written as equation.
- In the case that an environmentally friendly final product can substitute a primary one on the sales market, limited demand can be considered. Let i_π be the index of the primary final product and i_ε be the index of the environmentally friendly one. The constraint that to the customer with index f it is not possible to sell more of the primary and environmentally friendly final product than the maximum possible sold quantity of the primary product is written as follows:

  $$z_{i_\pi f} + z_{i_\varepsilon f} \leq D_{i_\pi f} .$$

  Further, to the customer with index f we have to sell at least $d_{i_\varepsilon f}$ units of the environmentally friendly product, otherwise we are not allowed to sell the primary product. Using zero-one variable $u_{i_\varepsilon f}$, where the value of $u_{i_\varepsilon f}$ is 1 when it is optimal to sell the environmentally friendly product, the corresponding constraints are written as follows:

  $$d_{i_\varepsilon f} u_{i_\varepsilon f} \leq z_{i_\varepsilon f} ,$$
  $$z_{i_\pi f} \leq D_{i_\pi f} u_{i_\varepsilon f} .$$

- When the i-th element is a production element, two possibilities can arise. In the first case the chain of production activities is not changed since per unit of production activity the consumed quantity of the environmentally friendly production element is equal to the consumed quantity of the primary one. Let us assume that there are two sources of the production element, the h_π-th of the primary and the h_ε-th of the environmentally friendly one. Considering the environmental quality of the element at the source's index, let us write the claim for the whole source substitution:

  $$y_{ih_\pi} \leq B_{ih_\pi}(1 - u_{ih_\varepsilon}) ,$$

  $$y_{ih_\varepsilon} \leq B_{ih_\varepsilon} u_{ih_\varepsilon} ,$$

  where the value of zero-one variable u_{ih_ε} is 1 when it is optimal to purchase from the source of the environmentally friendly element, otherwise it is 0. Similarly, lower bounds can be multiplied with zero-one variable u_{ih_ε}. In the second case a special chain of production activities arises since per unit of production activity the consumed quantity of the environmentally friendly production element is not equal to the consumed quantity of the primary one. For the i-th environmentally friendly production element, which is a new relevant element, the material balance constraint (1) without the first and the fourth term is constructed.

When the results of the simulations of the environmentally oriented business process are obtained by using the described optimization models, other potential indicators of the production process efficiency (see, e. g. [4]) can be developed in co-operation between experts of different professions, considering the characteristics of a particular system.

3. THE MULTICRITERIA METHOD FOR THE EVALUATION OF BUSINESS PROCESSES: A PRACTICAL CASE

The basic method for environmentally oriented business decision-making by simulations and by using optimization models as scenarios has already been applied in the processing industry [7]. In this article we present the completed method for the evaluation of environmentally oriented business processes with a practical case from the Slovene enterprise “Termoplast Bistrica ob Dravi”. In this enterprise packaging for diary products is produced. The materials used are polypropylene (PP), which is generally considered environmentally friendlier, and polystyrene (PS), which is generally considered environmentally less friendly (see, e. g. [1]). We briefly describe different business alternatives together with the corresponding optimal values, obtained by the method for environmentally oriented business decision-making. Special attention is given to the criteria that are selected according to the particularities of these practical business processes. Further, we introduce the calculation of the criteria weights according to the results of the research in the Slovene processing industry (Research 1), and the alternatives’ input data according to the managers’ and experts’ judgements in Termoplast (Research 2).

The basic method for environmentally oriented business decision-making was used in four simulations to obtain four business alternatives:

1. Simulation 1 gives the optimal business process realization for the initial business process. We had to include different possibilities for particular parts of the business process. We completed the obtained model with the claim that all of the useless waste must be disposed of, whereas all of the useful waste must be processed, sold or disposed of. Therefore, the balance constraints (1) for different types of waste are written as equations. Element and market data as well as technological data of the considered business process were inputted with an appropriate computer program [10] that constructed the linear model of the business process, too. When the model is verified, it can be used as a scenario of the business process for the evaluation of environmentally oriented business decisions.
2. Simulation 2 includes some possibilities for an integrated approach to environmental management. Environmental degradation is decreasing with waste recycling that is included in the production process in Termoplast. Eco-balances show that - put together - the effect of the substitution of PS products with PP ones on the environment is favourable [1]. Simulation 2 includes also market research for environmentally friendly materials and products, the

substitution of PP and PS materials, the minimum quantity of the environmentally friendly PP material that has to be purchased if they want to purchase PS material in the future, and the changes being made to existing PS products.

3. Simulation 3 is completed by investment possibility into the capacities for PP final products' production and by substitution of production processes.
4. Simulation 4 includes investment possibility into the capacities for PS final products' production.

In the completed method we included the following optimal results, obtained with the basic method: the optimal contribution and eventual progressive fixed costs, the optimal consumed quantities of machine capacities, the optimal consumed quantities of PP and PS materials and the optimal cost of the waste disposal.

Besides quantitative business results that are obtained by simulations with the models – scenarios of the business processes, other criteria that are relevant to the goal – the evaluation of environmentally oriented business processes - were determined by considering the results of Research 2. Following the impacts of business processes with PP and PS materials on the environment, top managers and experts from different enterprise business fields structured the problem as is shown in Figure 1.

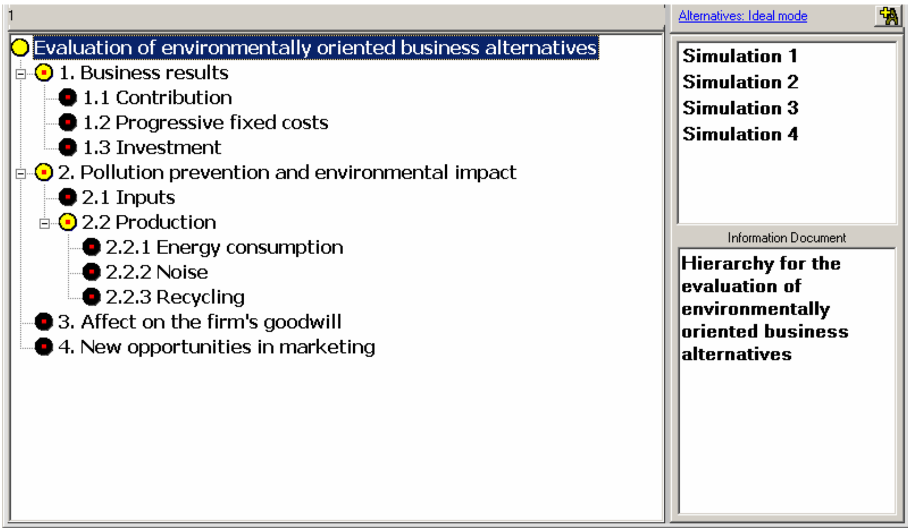

Figure 1: Hierarchy for the evaluation of environmentally oriented business alternatives

Business results, pollution prevention and environmental impact, affect on the firm's goodwill and new opportunities in marketing are defined as general criteria. We determined the importance of these criteria with respect to goal by considering the research results on the causes for environmental activities in the enterprises of the processing industry (Research 1). Percentages of the sample enterprises that found a particular possibility as the cause for environmental activities in enterprises are presented in Table 1. Following them, we can express the weights of general criteria as the proportion of the enterprises that consider a particular cause by

$$w_k = \frac{P_k}{\sum_k P_k}, \; k = 1, 2, \ldots, n, \tag{7}$$

where w_k is the weight of the k-th criterion and P_k is the datum for the k-th weight. These weights are presented in Table 1. Using (7), the weights of sub-criteria can be calculated as well.

Table 1: Causes for environmental activities in enterprises

Cause for environmental activities in enterprises	Percentage of enterprises*	General criterion weight w_k
1. Business results	26.6	0.1501
2. Pollution prevention and environmental impact	63.3	0.3572
3. Affect on the firm's goodwill	55.7	0.3144
4. New opportunities in marketing	31.6	0.1783

*In the research on environmentally oriented business decision-making, performed in 79 enterprises in the Slovene processing industry during November and December 2001, decision makers and experts in these enterprises chose several (more than one) causes, written in the questionnaire.

Emphasizing current business decision-making, we assessed the importance of the secondary sub-criteria 1.1 - Contribution, 1.2 - Progressive fixed costs and 1.3 - Investment with respect to the criterion 1. - Business results by graphical assessment. Transformed into verbal assessment, the judgements on importance, presented in Figure 2, are as follows:

- Contribution is strongly more important /5/ than Progressive fixed costs,
- Contribution is extremely more important /9/ than Investment,
- Progressive fixed costs are slightly to moderately more important /1.7/ than Investment, where for the last comparison magnified scale is used.

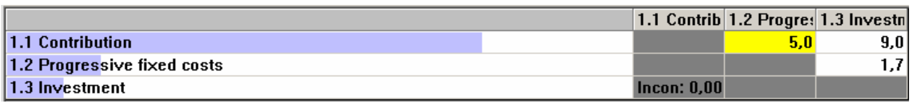

Figure 2: Pairwise comparisons of the business results' sub-criteria importance

The optimal values of contribution, progressive fixed costs and investment, obtained in Simulations 1, 2, 3 and 4 where optimization models of total business processes were used as scenarios, are presented in Table 2. The optimal progressive fixed costs are classified in 7 classes and investments are classified in 5 classes and assigned scores.

Table 2: The data about business results

Simulation	1.1 Contribution	1.2 Progressive fixed costs		1.3 Investment	
	(optimal results in monetary units)	(optimal results in monetary units)	Assigned score	(in monetary units)	Assigned score
Simulation 1	13716	0	7	0	5
Simulation 2	15285	45	7	0	5
Simulation 3	16168	141	5	14850	4
Simulation 4	17580	256	2	49500	1

The importance of the secondary sub-criteria 2.1 - Inputs and 2.2 - Production with respect to the general criterion 2. - Pollution prevention and environmental impact is determined considering the research results on the importance of environmental management in business functions in the sample enterprises in the processing industry (Research 1). Following the percentage of the sample enterprises that see environmental management important in purchasing and those that see environmental management important in production, we calculated the importance of inputs and production by (7) where the index of each sub-criterion under the k-th criterion is used instead of k. They are presented in Table 3.

Table 3: Importance of environmental management in business functions

Business function	Percentage of enterprises	Secondary sub-criterion	Secondary sub-criterion importance
Purchasing	67.1	2.1 Inputs	0.4241
Production	91.1	2.2 Production	0.5759

To obtain the data about the sub-criterion 2.1. - Inputs, eco-balances of the second generation were taken into consideration by following eco-points for PP and PS. Eco-points that are determined by the method of ecological scarcity are given to energy consumption, air burden, water burden and fixed waste [1]. The totals of environmental burden are 270 eco-points for PP and 317 eco-points for PS [1]. We obtained the data about Inputs in the t-th simulation V_t, presented in Table 4, so that we summarized the optimal quantity of consumed PP materials in the business process in the t-th simulation PPC_t*, multiplied with the corresponding eco-points, and the optimal quantity of consumed PS materials in the business process in the t-th simulation PSC_t*, multiplied by the belonging eco-points:

$$V_t = 270PPC_t * + 317PSC_t * , \quad \forall t .$$

Table 4: The data about inputs

Simulation	Consumption of PP materials PPC_t* (optimal results in t)	Consumption of PS materials PSC_t* (optimal results in t)	Inputs V_t
Simulation 1	0.835	52.052	16726
Simulation 2	10.907	50.005	18796
Simulation 3	14.822	49.799	19788
Simulation 4	11.383	99.071	34479

Since more eco-points reflect more serious environmental impact, we inverted the values, entered with the computer program Expert Choice [8].

The importance of the tertiary sub-criteria 2.2.1 - Energy consumption, 2.2.2 - Noise and 2.2.3 – Recycling with respect to the secondary sub-criterion 2.2 - Production is determined considering the research results on environmental assessment fields in the enterprises of the processing industry (Research 1). We followed the percentages of the sample enterprises that consider energy consumption, noise and recycling as fields of environmental assessment. Together with the importance, obtained by (7) where the indexes of the sub-criteria 2.2.1 - Energy consumption, 2.2.2 - Noise and 2.2.3 – Recycling are used instead of *k,* they are written in Table 5.

Table 5: Importance of environmental assessment fields

Environmental assessment field	Percentage of enterprises	Tertiary sub-criterion importance
2.2.1 Energy consumption	77.2	0.333
2.2.2 Noise	70.9	0.306
2.2.3 Recycling	83.5	0.361

The data about the sub-criterion 2.2.1 - Energy consumption in the *t*-th simulation CE_t, written in Table 6, are obtained following the optimal consumed capacities of the machines in the business process in the *t*-th simulation CC_{it}*, and energy consumption per unit of the machines whose capacities are consumed in the optimal solution a_i. In each simulation, we summarized the consumed energy of these machines:

$$CE_t = \sum_i a_i CC_{it}^*, \quad \forall t .$$

Table 6: The data about energy consumption, noise and recycling

Simulation	Energy consumption in production process CE_t	Noise in production process N_t	Within company recycling efficiency $WCRE_t$
Simulation 1	142137	173994	0.00176
Simulation 2	159748	224270	0.00156
Simulation 3	172648	259367	0.00147
Simulation 4	236943	306008	0.00154

The data about the sub-criterion 2.2.2 - Noise in the *t*-th simulation N_t are written in Table 6 as well. They are obtained following the optimal consumed capacities of the machines in the business process in the *t*-th simulation CC_{it}*, and noisiness of the machines whose capacities are consumed in the optimal solution ν_i:

$$N_t = \sum_i \nu_i CC_{it}^*, \quad \forall t .$$

The data about the sub-criterion 2.2.3 – Recycling are expressed with the "Within company recycling efficiency" in the *t*-th simulation $WCRE_t$ and presented in Table 6.

This indicator is calculated considering the optimal values of the cost of the waste disposal WC_t* and contribution (5) C_t*:

$$WCRE_t = \frac{WC_t^*}{C_t^*}, \quad \forall t .$$

When assessing the affect on the firm's goodwill with respect to environmental burden in Research 2, managers and environmental experts in Termoplast expressed that the business process with PP is moderately more preferred /3/ than the business process with PS materials. The weight of the production with PP materials is therefore 0.75 and the weight of the production with PS materials is 0.25. For the *t*-th simulation, we summarized the products between the proportion of the production with PP materials PP_t with the corresponding weight, and the proportion of the production with PS materials PS_t with the corresponding weight:

$$AFG_t = 0.75PP_t + 0.25PS_t , \quad \forall t .$$

The obtained data are given in Table 7.

Table 7: The data about affect on the firm's goodwill and new opportunities in marketing

Simulation	Proportion of the consumption of PP materials PP_t	Proportion of the consumption of PS materials PS_t	Affect on the firm's goodwill AFG_t	New opportunities in marketing NOM_t
Simulation 1	0.016	0.984	0.25800	0.2096
Simulation 2	0.179	0.821	0.33950	0.3074
Simulation 3	0.229	0.771	0.36450	0.3374
Simulation 4	0.0125	0.9875	0.25625	0.2075

When assessing new opportunities in marketing with respect to environmental burden in Research 2, managers and environmental experts expressed also that the business process with PP is moderately to strongly more preferred /4/ than the business process with PS materials. The weight of the production with PP materials is therefore 0.80 and the weight of the production with PS materials is 0.20. For the *t*-th simulation we summarized the products between the proportion of the production with PP materials PP_t with the corresponding weight, and the proportion of the production with PS materials PS_t with the corresponding weight:

$$NOM_t = 0.8PP_t + 0.2PS_t , \quad \forall t .$$

The obtained data are given in Table 7 as well.

Synthesizing this multicriteria decision-making problem (as it is written in Introduction describing the fourth step of the applied technique) with Expert choice [8] (see Figure 3) it can be concluded that the business process in Simulation 3 (where investment in the machine capacity for the production with PP materials is realized) is the alternative with the highest final value (overall priority) among environmentally oriented business processes. It is followed by Simulation 2 with included possibilities of integrated environmental protection and improvement in the business process, Simulation

1 with the initial business process and Simulation 4 where investment in the production with PS materials that are generally considered environmentally less friendly is realised.

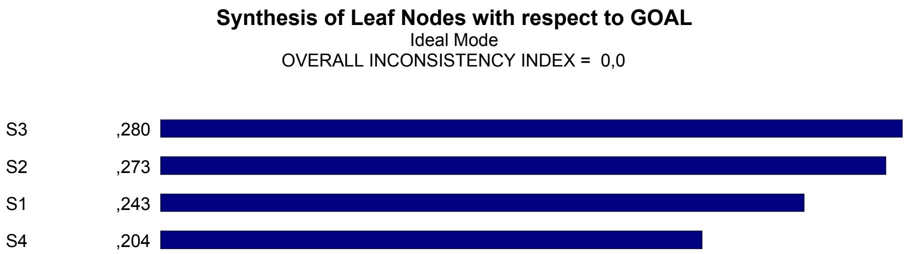

Figure 3: Final values of environmentally oriented business processes

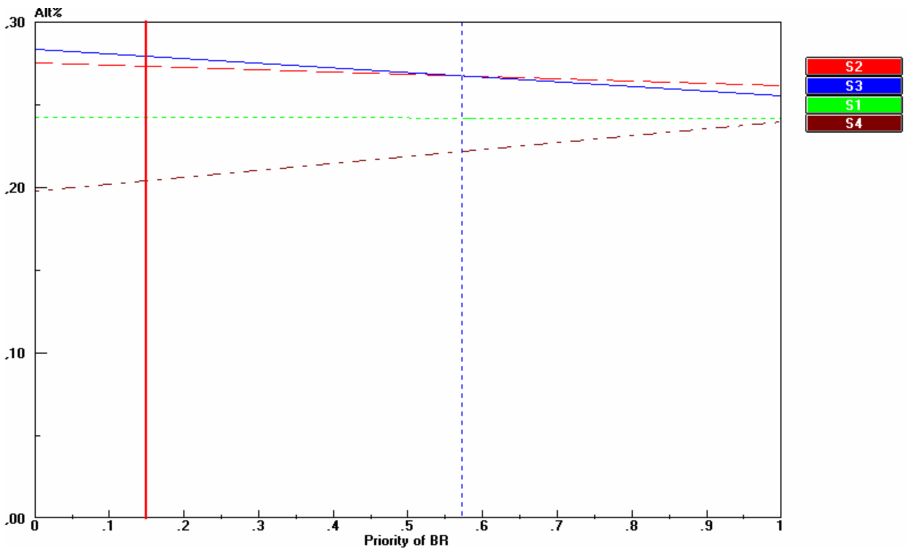

Figure 4: Gradient sensitivity graph: business results with respect to goal

Decision makers can study the impact of changes in the criteria weights on the evaluation of business process with different types of sensitivity analysis. For example, Figure 4 shows that the weight for the general criterion 1. - Business results should be more than 0.56 to replace the business process in Simulation 3 with the business process in Simulation 2 as the most acceptable one.

4. CONCLUSION

The method presented in this article is applicable for the evaluation of environmentally oriented business processes in order to recognize the most acceptable one, especially in the processing industry. Since we consider the particularities of the business processes in the sample enterprise, the decision-makers' preferences, their judgments on importance and practical data about the business processes in this enterprise, as well as the research results on environmental management in the sample enterprises of the processing industry and those found in eco-balances, we found the AHP technique appropriate in connection with other decision-making tools.

The basic method for environmentally oriented business decision-making enables the preparation of business decisions about some fields of environmental assessment and integrated environmental protection and improvement, so that business results of enterprises are increased and environmental performance is improved. This method includes simulations where optimization models of total business processes, used to support decomposed and holistic decision-making, are used as scenarios. In this article we decomposed and included the possibilities of integrated environmental protection and improvement in the optimization model of the multiphase business process. The optimal results are used in the completed method, together with the data for other criteria that managers and environmental experts found relevant to this problem. It has turned out that approaching the problem step by step, described in this article, enables experts and managers to use this method for the goal fulfillment. The AHP technique together with the appropriate computer program Expert Choice is used when structuring the problem. When establishing priorities, pairwise comparisons are successfully applied in the assessment of the importance of the sub-criteria 1.1 – Contribution, 1.2 – Progressive fixed costs and 1.3 – Investment with respect to the criterion 1. – Business results. Moreover, pairwise comparisons are applied to obtain the weights of the production processes with PP and PS materials when assessing the affect on the firm's goodwill and new opportunities in marketing with respect to environmental burden. In order to recognize the environmentally oriented business process that is most acceptable regarding environmental and business criteria, the ideal mode of synthesis should be applied. If an enterprise wants to perform more business processes, it should apply the distributive mode of synthesis. Further, decision makers can study the increasing impact of environmental criteria on the selection of business processes by sensitivity analysis. Using the completed method and the appropriate computer program can help decision makers to understand the relationships among criteria that influence the evaluation of environmentally oriented business processes, to investigate possible misunderstandings and to improve the model for choosing the most acceptable environmentally oriented business process by their evaluation. With the inconsistency ratio, these decision makers can conclude that the importance, assessed to the considered criterion, is over- or undervalued. Studying them, they can improve their understanding of the relationships among the criteria, and of the criteria meaning and importance as well.

Future research will be directed towards model structuring for this problem in other industrial branches, as well as towards the AHP applications in environmental benchmarking, and in the assessment of enterprises' creditworthiness. In our case the method helps a medium-sized enterprise in short-term business decision-making regarding the evaluation of business processes. To use this approach in long-term or strategic decision-making process, the information basis should be improved by more criteria (e.g. knowledge related factors, the assessment of strategy, business moral and organizational culture), compared by industry related information, and benchmarks. The purpose of our future research work is therefore to develop and apply a tool for benchmarking of environmentally oriented business processes in order to achieve business process excellence. Since improvements of business processes are important not only for multinationals because of global competition and quality awards, but are necessary also for survival of small and medium sized enterprises, the objectives of our future work are to identify the weaknesses of environmentally oriented business processes, to suggest improvement measures and to develop a method in order to help in decision-making about business process reengineering and selection of new production processes. Another purpose of our future research work is to develop and apply the method for internal rating to select among business partners on the basis of their creditworthiness evaluation.

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