Analysis of Decision Criteria for Sustainable Business Plan

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It is urgent for present and future generations to find a way for environmental sustainability and company's development to be compatible. Experience shows that profit itself does not guarantee the sustainable development. The approach described in the paper presents the way of how different economic and environmental criteria are applied in searching for a business plan which meets both environmental requirements and decision maker's preferences on those criteria. An index of acceptance is introduced to indicate how well the obtained business plan meets the decision-maker's preferences. The model is tested on artificially generated data.

Keywords: Mixed Integer Linear Model, Analytic Hierarchy Process, Sustainable Development

1. Introduction

The main goal of the majority of companies is to ensure such growth and development which enables them to profitably meet the increasingly demanding requirements of customers. Profit is an important prerequisite for achieving this goal as well as the indicator of how successful a company is in achieving it. For this reason, the profit is used as a criterion in selecting the best business plan. As it depends on the market share of the company's products, its image and the number of company's new products launched at the market, it is essential that all these factors are included in evaluation of a business plan, too. Taking into consideration the right of future generations to meet their own needs, the list of criteria should include environmental criteria (Magretta, 1997). Among these, the most important are the quantity and danger of pollutants which arise in manufacturing and consumption of the company's products as well as the consumption of vital environmental resources during the manufacturing and consumption.

By evaluating business plans the decision-maker will consider only those environmental impacts prescribed by the current regulations in force. The others will influence his decision only if they contribute to achieving the company's main goal.

Experience shows that profit itself does not guarantee sustainable economic growth. The situation will probably remain the same until environmental regulations do not change or environmental impacts become one of the most important quality dimensions of products. The time in which this situation should be changed is unfortunately limited. This represents a challenge for researchers to assist in finding solutions which promote the process of achieving sustainable development.

This approach is based on the assumption that the decision-maker takes the final decision on which business plan leads the company towards long-term prosperity in accordance with their judgements about the significance of objectives in achieving the main goal. For this reason, the list of objectives is enhanced by a new one, i.e. the decision-maker's preferences.

Considering all that, the following criteria should be taken into account in evaluating the business plan:

- profit
- market shares of products
- number of new products
- the company's environmental image
- quality of products

- the decision-maker's judgements on the importance of objectives

In many cases, sustainable development is not possible without investments in new, environmentally responsible products or new technology. S. Hart (1997) proposes the following strategies which lead the company towards sustainable development:

- Pollution prevention strategy presents the shift from pollution control to pollution prevention. It depends on continuous improvement efforts to reduce waste and energy use.
- Product stewardship strategy focuses on minimizing not only pollution from manufacturing but also all environmental impacts associated with the full life cycle of a product. Minimization can be achieved by the product's design for environment. It enables a smaller consumption of environmentally vital resources, zero emission and easier reuse or recycling of products.
- Clean technology which is desperately needed in the emerging economies presents an unprecedented opportunity for a company to develop new products and process technologies.

The aim of this paper is thus to present an approach based on information technology which aids a decision-maker to find such a business plan which would meet the company's goals and reduce its environmental nuisance. The paper is organized as follows. The criteria for evaluating feasible business plans are introduced in Section 2. Section 3 contains the introduction of different optimization models with optimal solutions which lead a company towards sustainable development. The approach described is presented on a numerical example in Section 4.

2. Criteria for Evaluating Business Plans

From the environmental point of view, it is important that the quantities of pollutants are measured and the sources of pollution are revealed. For that reason, the following notation is used for mathematical expression of criteria and constraints:

x_j – unknown quantity of the jth transformation activity,

z_i – unknown sold quantity of the ith element,

y_i – unknown purchased quantity of the ith element,

u_i, – zero-one variable, $u_i = 1$ if the ith investment decision is chosen, and zero otherwise,

$m_j : \mathbf{R} \to \mathbf{R}$ – marginal costs of the jth transformation activity arising due to the consumption of irrelevant elements,

$q_{ij} : \mathbf{R} \to \mathbf{R}$ – quantity of the ith element consumed per unit of the jth transformation activity,

$r_{ij} : \mathbf{R} \to \mathbf{R}$ – quantity of the ith element produced per unit of the jth transformation activity,

$s_i : \mathbf{R} \to \mathbf{R}$ – purchasing price of the ith element or operating cost per unit of capacity,

$c_i : \mathbf{R} \to \mathbf{R}$ – selling price of the ith element,

f_0 – current fixed costs,

f_i – the change of the current fixed costs arised due to the ith investment,

e_i – unallocated quantity of the ith element,

d_i – minimal quantity of the ith element which has to be sold,

D_i – maximal quantity of the ith element which can be sold,

b_i – minimal quantity of the ith element which has to be purchased,

B_i – maximal quantity of the ith element which can be purchased,

E – index set of the existing relevant elements,

I – index set of relevant elements which can be consumed, manufactured or used only if the investment decision is implemented,

C – index set of relevant elements for which sources outside the production process exist,

S – index set of elements having customers,

R_i – index set of the transformation activities producing the ith element,

Q_i – index set of the transformation activities consuming the ith element,

H – index set of the activities transforming the pollutants in harmless stuff.

Profit is defined by:

$$P = R - CP \qquad (1)$$

where R means revenue and CP production costs.

The company's revenue is defined by:

$$R = \sum_{i \in S} c_i(z_i). \qquad (2)$$

If c_i is concave piecewise linear, then (2) can be transformed to a linear function by applying the following substitution

$$z_i = z_{i1} + z_{i2} + \ldots + z_{ik_j} \qquad (3)$$

where z_{ij} expresses the quantity of the ith element sold at the price c_{ij}. The lower and upper bound for variable z_{ij} are defined by zero and the maximal quantity of the ith element, which can be sold at the price c_{ij}, respectively. k_i denotes the number of intervals for variable z_i. (Mesko, 1987.).

The company's production costs are defined by:

$$CP = \sum_{i \in C} s_i(y_i) + \sum_{j} m_j(x_j) + \sum_{i \in I} f_i u_i + f_0. \qquad (4)$$

In (4), the first and the second sum express the costs of consumed relevant and irrelevant elements, respectively. The third sum presents the increase of fixed costs caused by an investment decision. The last term is equal to current fixed costs. If the decisions under examination do not influence the current amount of fixed costs, f_0, they are not included in (4). In this case, maximal contribution is taken as the criterion of evaluation. If s_i and m_j are convex piecewise linear, then (4) can be transformed to a linear function by applying substitutions:

$$y_i = y_{i1} + y_{i2} + \ldots + y_{ih_i} \qquad (5)$$
$$x_j = x_{j1} + x_{j2} + \ldots + y_{jl} \qquad (6)$$

where y_{ij} means the quantity of the ith element purchased at the price s_{ij}, and x_{jk} the quantity produced by the jth activity at cost m_{jk}. The lower and upper bound for variable y_{ij} are defined by zero and the maximal quantity of the ith element, which can be purchased at the price s_{ij}, respectively. h_i expresses the number of intervals for variable y_i. The lower and upper bound for variable x_{jk} are defined by zero and the maximal quantity manufactured by the jth activity at the cost m_{jk}. The number of intervals for variable x_j is denoted by l.

The market share of the ith element produced for sale is defined by:

$$\frac{z_i}{TD_i} \qquad (7)$$

where TD_i equals a total market demand of the ith element.

The company's environmental image depends on many factors. Among the most important ones are the quantity and the impact of the pollutants on the environment caused by the production and consumption of products and services. Therefore, additional environmental costs which would arise due to the transformation of pollutants in the environmentally harmless stuff can be taken as the measure of the company's impact on the environment. They present a good measure because they include both the quantity of pollutants and the efforts needed to transform them into harmless stuff. The environmental costs are defined by:

$$CE = \sum_{i \in C} s_i(y_i) + \sum_{j \in H} m_j(x_j) + \sum_{i \in I} f_i u_i - \sum_{i \in S} c_i(z_i). \qquad (8)$$

In (8), the first and the second sum express the costs of relevant and irrelevant elements, respectively, consumed by the transformation of pollutants in harmless stuff. The third sum presents the increase of fixed costs caused by the purchase of the new machines needed by transformation activities. The costs defined by (8) do not include that part of the environmental costs which are incorporated in (4). In searching for the solution about which performance contributes to the improvement of the company's environmental image, the cost-effective ratio can be used as the objective function (Bastic, 1998.). It is defined by:

$$\frac{R}{CP + CE}, \qquad (9)$$

R, CP and CE are defined by (2), (4) and (8), respectively. It shows the company's cost effectiveness in transforming one monetary unit of inputs into outputs in the sustainable way. For this reason, it can be applied as one of the criteria in assessing the company's trustworthiness.

An index of acceptance is introduced to indicate how well the obtained solution meets the decision- maker's preferences. An AHP model is used to calculate its value, which is positive and not larger than one. In order to use the AHP model, the range of possible values for each criterion is split into smaller non-overlapping intervals. These intervals are incorporated in an AHP model instead of alternatives. By applying pairwise comparisons, the decision-maker specifies their judgements on the relative importance of each of the selected criteria and indicates their preferences for each of the defined intervals relative to the criterion (Dyer and Forman, 1991.). The priorities for criteria and their values or intervals are used in evaluating the solution, considering the value of each criterion obtained by the solution. For the *j*th solution, the value of the index of acceptance (IOA_j) is defined by:

$$IOA_j = \sum_k \left(\frac{w_{ik} w_k}{w_{ik,max}} \right) \tag{10}$$

where w_k means the priority of the *k*th criterion, w_{ik} the priority of values belonging to the *i*th interval and the *k*th criterion, and the optimal value of the kth criterion obtained by the *j*th solution belongs to the *i*th interval. w_k is defined by:

$$w_k = \sum_i w_{ik} \quad \text{where} \quad w_{ik,max} = \max_i w_{ik}.$$

The index of acceptance belonging to the ideal solution which possesses the best values of all criteria is equal to one. Regarding other solutions, it shows how close they are to the ideal solution. Therefore, it assists the researchers in finding an acceptable solution for the decision-maker, which leads the company towards sustainable development.

The quality of products can be assessed by objective criteria like the quantity of scrap and rework, which increase the production costs and, therefore, can be included in an optimization model. The customer driven quality is usually assessed by subjective estimates and therefore descriptive estimates are used for the quality of products manufactured by the process presented in the solution under examination. In calculating the index of acceptance, both kinds of estimates can be taken into account. Price of the product is also a factor which enables us to include the customer driven quality in an optimization model. Namely, it is expected that the products with customer driven quality can be sold at a higher price.

Our aim is to find such a solution which leads a company towards sustainable development and has the highest possible value of the index of acceptance. The problem is very complex for different objectives (some of them are in direct conflict), different possible investment decisions and different limitations must be considered. Optimization models can help in managing this complexity.

3. Optimization Models

The market share of products, the manufactured quantity of pollutants and the consumption of environmentally vital resources can easily be calculated if the following constraints are constructed for each relevant element:

$$e_i = \sum_{j \in R_i} r_{ij}(x_j) + y_i - \sum_{j \in Q_i} q_{ij}(x_j) - z_i \geq 0, \quad i \in E \cup I \tag{11}$$

$$d_i \leq z_i \leq D_i \quad i \in E \tag{12}$$

$$b_i \leq y_i \leq B_i \quad i \in E \tag{13}$$

$$d_i u_i \leq z_i \leq D_i u_i \quad i \in I \tag{14}$$

$$b_i u_i \leq y_i \leq B_i u_i \quad i \in I \tag{15}$$

The balance constraint (11) assumes that the sum of consumed and sold quantities can not exceed the available quantity of the *i*th element. If r_{ij} is concave piecewise linear and q_{ij} is convex piecewise linear, then substitution (6) is applied to transform (11) into a linear constraint. The market limitations give rise to the inequalities (12) – (15). It is expected that sustainable development cannot be achieved without investments. The constraint (14) assures that new, environmentally responsible product cannot be sold if the investment in the product's development is not accepted. The similar explanation can be applied for investment in new machines, which is considered by constraint (15).

Many optimization models support the search for solutions leading a company towards sustainable development. Some of them are:

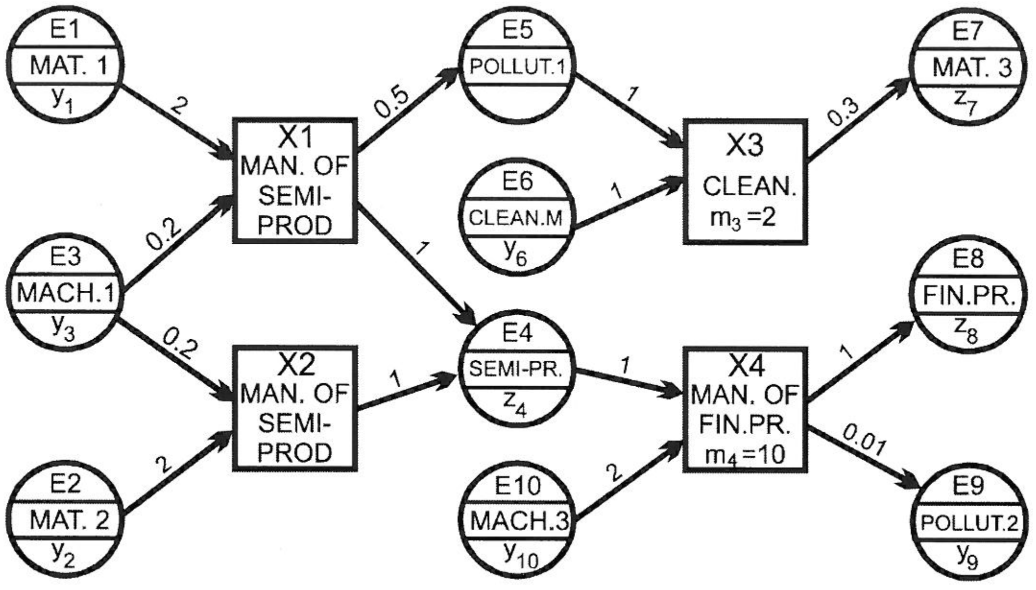

Fig. 1. Petri net

- The linear mixed integer-programming model defined by objective function (1) subject to nonnegative variables z_i, y_i, x_j, zero-one variable u_i, and constraints defined by (11)–(15).

- The linear mixed integer-programming model with an objective function defined as the difference between the profit determined by (1) and additional environmental costs defined by (8) subject to nonnegative variables z_i, y_i, x_j, zero-one variable u_i, and constraints defined by (11)–(15).

- The linear mixed integer problem with fractional mixed integer objective function defined by (9) subject to nonnegative variables z_i, y_i, x_j, zero-one variable u_i, and constraints defined by (11)–(15).

- The linear mixed integer problem with objective function defined by (7) subject to nonnegative variables z_i, y_i, x_j, zero-one variable u_i and constraints defined by (11)–(15).

The decisions obtained by the models mentioned above or with any other models differ in values of criteria applied in evaluation. From environmental viewpoint, the solutions are evaluated by the quantity and danger of pollutants for the environment as well as the consumption of environmentally vital resources. The decision-maker evaluates solutions considering profit, market share of products, number of new products and quality of products. The researcher's task is to find a solution which meets both the environmental and decision-makers' requirements. The index of acceptance is an appropriate tool in assessing the fulfilment of all those requirements.

4. Numerical Example

Let us consider a company producing a semi-product and a final product. Its manufacturing process is presented by Petri net in Figure 1.

In Figure 1, elements like materials, machines, semi-products, final products and pollutants are presented by allocation nodes in form of circles. Processes such as manufacturing of semi- products and final products, recycling are presented by transformation nodes. Semi-product (E4) can be manufactured by two processes denoted by X1 and X2. Pollutant 1 (E5) is obtained if semi-product is produced by process X1. By current regulations in force, the total quantity of this pollutant must be cleaned. The second pollutant (E9) is obtained by the manufacture of the final product. There are no regulations which would require its recycling by a company. Recycling would cause additional costs, therefore, the company has no short-term interest in doing it. The company's market opportunities and limitations are given in Table 1.

In Table 1, the variables y_1 and y_2 present the purchased quantity of material 1 and 2, respectively, expressed in tones, the variable y_3

Symbol	Element	Unit	Variable	Price or cost	Available quantities
E1	Material 1	t	y_1	8	1,250
E2	Material 2	t	y_2	9	1,000
E3	Machines 1	day	y_3	10	75
E4	Semi-product	t	z_4	25	
E5	Pollutant 1	m^3			
E6	Clean machine	m^3	y_6	15	500
E7	Material 3	l	z_7	3	
E8	Final product	1,000 p	z_8	62	15
E9	Pollutant 2	1,000 l	y_9	(1,500)	
E10	Machine 3	day	y_{10}	12	25

Table 1. Market data

presents the utilized capacity of machines 1 expressed in days. As we can see from Figure 1, the semi-product (E4) can be consumed by activity X4 or sold. The variable z_4 indicates its sold quantity expressed in tons. The available capacity of the elements E3, E6 and E10, the maximal suply of the elements E1 and E2, and the maximal demand for element E8 are given in the last column. In the column 'Price or Cost' of Table 1, the marginal operating costs of elements E3, E6 and E10 are given while for the other elements their prices are given. The costs of irrelevant elements denoted by m_j are given in transformation nodes in Figure 1.

Let us assume that the optimal solutions will be evaluated by the following criteria: profit, number of new products, market share of semi-product and final product, and produced quantity of pollutant 2 released in the environment. In calculating market shares, we take that the total demand of semi-product and final product is 3,000 t and 100,000 pieces, respectively. Current fixed costs amount to 1,000 monetary units (m.u).

Taking into account company's available capacities and capabilities as well as market opportunities, a business plan can be obtained by the linear model defined by objective function (1) and constraints (11)–(13). Optimal solution obtained by this model and computer program LOMP (Mesko, 1997) offers no new products, but

$$\begin{array}{rl} \text{profit} & 912.5 \text{ m. u.} \\ \text{market share of semi product} & 12.1\% \\ \text{market share of final product} & 12.5\% \\ \text{quantity of pollutant 2} & 125 \text{ l} \end{array} \qquad (16)$$

For all feasible business plans, the profit is equal to the difference between the total revenues and the sum of variable and fixed costs. Nonobligatory-environmental costs are not included among variable costs in the computation of the company's profit.

In searching for the environmentally more responsible solution, the linear model with the objective function defined as the difference between profit and additional costs which arose due to the cleaning of the pollutant 2 can be used. Additional costs amount to 1,500 m.u. per 1,000 l of the pollutant 2. For our example the objective function is determined by:

$$\max(25z_4+3z_7+62z_8-8y_1-9y_2-10y_3-15y_6 - 12y_{10} - 2x_3 - 10x_4 - 1500y_9) \quad (17)$$

Optimal solution attained by the objective function (17) and constraints (11)-(13) offers no new products but

$$\begin{array}{rl} \text{profit} & 875 \text{ m. u.} \\ \text{market share of semi product} & 12.5\% \\ \text{market share of final product} & 0 \\ \text{quantity of pollutant 2} & 0 \end{array} \qquad (18)$$

The same values of criteria as shown in (18) are obtained if the linear model defined by the objective function (9) and constraints (11)–(13) is solved.

Let us suppose that two investment proposals which lead the company towards sustainable development are available but only one can be carried out. They are:

- Investment in a new machine,
- Investment in a new, environmentally responsible product.

Symbol	Element	Unit	Variable	Cost	Available capacity
E11	New machine	day	y_{11}	8	25
			u_{11}	200	

Table 2. Data on new machine

The investment in the purchase of a new machine enables a company to increase the environmentally responsible production of a semi-product. Manufacturing of the semi-product with a new machine denoted by X_5 requires less material 2 (1.5 t per ton of semi-product) and less machine capacity (0.15 day per ton of semi-product). The other data are given in Table 2.

If maximal profit is taken as the objective function in optimization model, the feasible business plan can be obtained by the optimal solution of a mixed integer model with objective function (1) and constraints (11)–(15). It is calculated by the computer program MIXIN (Mesko, 1997). Elements with indices 1 to 10 belong to set E, while element E11 belongs to set I. In objective function (1), the variable operating costs associated with new machine are considered by term $8y_{11}$ and the monthly increase of fixed costs is included by term $200u_{11}$. The constraint

$$y_{11} \leq 25u_{11}$$

prevents both that the capacity of the new machine is utilized in the case when the investment decision is not accepted as well as that the capacity can not be utilized more than 25 days in a month if the investment decision was accepted. In this case, the optimal solution obtained offers no new products, but

$$\begin{array}{rl} \text{profit} & 2,429.175 \text{ m. u.} \\ \text{market share of semi product} & 17.6\% \\ \text{market share of final product} & 12.5\% \\ \text{quantity of pollutant 2} & 125 \text{ l} \end{array} \tag{19}$$

If the maximal difference between profit and additional nonobligatory-environmental costs is taken as the criterion of optimization in model with constraints defined by (11)–(15), the following values of criteria are obtained by its optimal solution

$$\begin{array}{rl} \text{profit} & 2,391.675 \text{ m. u.} \\ \text{market share of semi product} & 18.1\% \\ \text{market share of final product} & 0 \\ \text{quantity of pollutant 2} & 0 \end{array} \tag{20}$$

The optimization model and its optimal solution needed for determining feasible business plan with the values of chosen criteria given in (20) are presented in the Appendix. The same optimal solution is obtained if maximal cost-effective ratio defined by (9) is taken as the objective function in a model with constraints defined by (11)–(15).

The investment in a new, environmentally responsible product provides the company with an opportunity to produce a new final product. Manufacture of the new product requires smaller quantity of semi-product (0.7 t per ton of semi-product), less capacity of machine (1.4 day per ton of semi-product) and gives smaller quantity of pollutant 2 (5 litres per 1 t of semi-product). Market data for the new product are given in Table 3.

Considering the life cycle of the new product and total development costs, the monthly fixed costs of 360 m.u. are obtained. Total quantity of the final product which can be sold is 20,000 pieces.

If the profit is taken as the objective of optimization, the feasible business plan can be obtained by optimal solution of linear mixed integer model with objective function (1) and constraints (11)–(15). Elements with indices 1 to 10 belong to set E, while element E12 belongs to set I. In objective function (1), the revenues associated with the new product are considered by term $62z_{12}$, the increase of fixed costs associated with the development of a new product

Symbol	Element	Unit	Variable	Price	Demand
E12	New final product	1,000 p	z_{12}	62	20
			u_{12}	360	

Table 3. Market data on the new product

is included by term $360u_{12}$. The limited market opportunities of the final product are determined by constraints

$$z_8 + z_{12} \leq 20$$
$$z_{12} - 20u_{12} \leq 0$$

The optimal solution obtained by this model offers one new product and

$$\begin{array}{rl} \text{profit} & 2.117 \text{ m. u.} \\ \text{market share of semi product} & 12\% \\ \text{market share of final product} & 20\% \\ \text{quantity of pollutant 2} & 100 \text{ l} \end{array} \quad (21)$$

In this particular case, the same optimal solutions are obtained if the cost-effective ratio defined by (9) or the difference between profit and additional environmental costs, are taken as the criterion of optimization.

By evaluating feasible business plans, all selected criteria and decision-makers' judgements on the relative importance of each criterion in terms of its contribution to the overall goal as well as their preferences for individual values that the criterion can take are all considered. Their judgements on relative importance of each of five criteria are specified in the matrix:

	msfp	mssp	nnp	qpoll
profit	3	4	4	6
msfp		2	2	4
mssp			1	1
nnp				1

where abbreviations mean: msfp – market share of final product, mssp – market share of semi-product, nnp – number of new products, qpoll - produced quantity of pollutant. The values in matrix have the following meaning: 1 – equally, 2 – equally to moderately, 3 – moderately, 4 – moderately to strongly, and 6 – strongly to very strongly preferred column element.

The profit values are split into five intervals, as follows:

800 -	999 m.u.	poor
1,000 -	1,399 m.u.	acceptable
1,400 -	1,799 m.u.	good
1,800 -	2,199 m.u.	very good
2,200 -	2,500 m.u.	excellent

The decision-maker also needs to indicate their relative preferences for each of the five intervals specified. Similarly is done for other four criteria. With computer program Expert Choice, Version 9.0 the following priorities for the selected criteria are obtained:

profit	0.488
market share of final product	0.223
market share of semi product	0.103
number of new products	0.103
produced quantity of pollutant	0.083

For possible profit values assigned to five intervals the following priorities and contributions to index of acceptance defined by (10) are obtained:

	Global priority	Contribution to index value
Poor	0.016	0.035
Acceptable	0.034	0.075
Good	0.070	0.154
Very good	0.146	0.321
Excellent	0.222	0.488

Now, we can calculate the index of acceptance for each of the feasible business plans with values of chosen criteria given in (16), (18), (19), (20) and (21). To illustrate, its calculation for the values of the criteria in (20) is presented in Table 4.

Of course, we need not calculate its value by ourselves. This task can be performed by program Expert Choice if it has data presented in column (1) and (3) of Table 4 for each feasible business plan.

Taking into account the value of the index of acceptance, the following rank order of the first three feasible business plans is obtained.

Investment in new machine defined by (20)	0.723
Investment in new product defined by (21)	0.711
Investment in new machine defined by (19)	0.669

Among all feasible business plans, the business plan with the investment in purchasing new machine for environmentally friendly production of semi-product best meets the decision-maker's preferences. This business plan does not bring the company the highest profit but it increases

Criteria	Value		Contribution to index value
	Quantitative	Descriptive	
(1)	(2)	(3)	(4)
Profit	2391.675 m.u.	Excellent	0.488
Market share of final product	0	Poor	0.023
Market share of semi-product	18.1%	Excellent	0.103
Number of new products	0	Poor	0.026
Quantity of pollutant	0	Excellent	0.083
Index of acceptance			0.723

Table 4. The computation of the index of acceptance

the current profit and reduces the harmful environmental impacts which is of particular importance for the sustainable development.

5. Conclusion

The current state of the environment presents a serious threat to the healthy life of our and future generations. Yet, it also creates the opportunities for companies to develop new technologies, products and services which would protect or even improve the quality of the environment. It is up to the decision-makers to recognize this threat and change it into their opportunities for the company's further growth.

The approach described enables the decision-makers to manage the complexity of decision-making caused by the increasing number of decision criteria and by many investment alternatives which must all be considered. One of its main advantages is that it permits the researchers to take into account the decision-makers' preferences regarding the quantitative and qualitative criteria (such as a company's environmental image, long-term perspective of a new product, etc.). Because the environment has not played a significant role in decision-making up to now, there has been little chance to apply such a model in practice. We believe that it should be changed very soon and the approach described will be a helpful tool in the search of the best business plan for sustainable development.

Further research should investigate the ways of including the decision-makers' preferences directly into an optimization model. Our wish is to encourage the decision-makers to seek for profitable decisions which will improve the quality of the environment.

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Appendix

A mathematical model when the maximal difference between profit and additional nonobligatory-environmental costs is taken as the criterion of optimization with constraints defined by (11)–(15).

maximize $-8y_1 - 9y_2 - 10y_3 + 25z_4 - 15y_6 + 3z_7 + 62z_8 - 1500y_9 - 12y_{10} - 8y_{11} - 200u_{11} - 2x_3 - 10x_4$

subject to

$$
\begin{aligned}
E1)\quad & y_1 - 2x_1 \geq 0 \\
& y_1 \leq 1250 \\
E2)\quad & y_2 - 2x_2 - 1.5x_5 \geq 0 \\
& y_2 \leq 1000 \\
E3)\quad & y_3 - 0.2x_1 - 0.2x_2 \geq 0 \\
& y_3 \leq 75 \\
E4)\quad & x_1 + x_2 + x_5 - x_4 - z_4 \geq 0 \\
E5)\quad & 0.5x_1 - x_3 = 0 \\
E6)\quad & y_6 - x_3 \geq 0 \\
& y_6 \leq 500 \\
E7)\quad & 0.3x_3 - z_7 \geq 0 \\
E8)\quad & x_4 - z_8 \geq 0 \\
& z_8 \leq 15 \\
E9)\quad & 0.01x_4 - y_9 = 0 \\
E10)\quad & y_{10} - 2x_4 \geq 0 \\
& y_{10} \leq 25 \\
E11)\quad & y_{11} - 0.15x_5 \geq 0 \\
& y_{11} - 25u_{11} \leq 0
\end{aligned}
$$

int $u11$

Optimal solution

$y_2 = 1000$, $y_3 = 75$, $z_4 = 541.667$, $y_{11} = 25$, $x_2 = 375$, $x_5 = 166.667$, $u_{11} = 1$, $y_1 = y_6 = y_9 = y_{10} = z_7 = z_8 = x_1 = x_3 = x_4 = 0$

Profit is equal to the difference between revenues and the sum of variable and fixed costs. Fixed costs are expressed with the last two summands.

$$
\begin{aligned}
541.667 * 25 - 1000 * 9 - 75 * 10 - 25 * 8 \\
- 200 - 1000 = 2,391.675
\end{aligned}
$$

Market share of semi-product equals

$$\frac{541.667}{3000} = 18.1$$

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