

ENVIRONMENTAL MANAGEMENT OF BUSINESS PROCESSES

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Since the decision-makers in enterprises will accept the goals of environmental management only if they are motivated enough, comprehensible and useful tools should be generated to support environmentally oriented business decision-making. For that reason, a general optimisation model of the multiphase business process is presented in this paper. This model includes the possibilities for an integrated approach to environmental protection so that it can be applied as a scenario by the business process simulation for the evaluation of environmentally oriented business decisions on business performance. Furthermore, development and application possibilities of the presented model are introduced. Some measures of resource efficiency are developed using the presented optimisation model.

1. INTRODUCTION

Environmentally unaware business operations in enterprises can lead to environmental destruction by consumption of elements, performance of processes and production of by-products. The term “environment”, as used in this paper, refers to the natural environment. This paper treats the term “enterprise” especially as a business system with the performance of a business process or with a business operation, which is characterised by entrepreneurship. Since some natural resources are not disposable in unlimited quantities or their exhausted quantities or degraded qualities can not be renewed, economic development is possible only as sustainable development (The Bruntland Report, 1987). In this way, “development which meets the

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needs of the present generation without compromising the ability of future generations to meet their own needs” (The Bruntland Report, 1987) can be made possible. With respect to environmental protection and sustainable development, which are the key components of environmental management, economic rationality is still the main management principle in enterprises. Without environmental management, numerous market opportunities are lost, risk is increased, additional cost can arise, and the opportunities for cost decreasing and income increasing that appear with recycling processes in the integrated environmental protection system are lost as well. Management must consider the requirements of environmentally oriented business partners, customers, stakeholders, banks and insurance companies, investors, public and media, as well as governments with environmental legislation. Therefore, the possibilities of integrated environmental protection should be systematically considered in business decision-making, especially in the enterprises in transition.

Although the benefits of environmentally oriented business decisions are described - see, e.g. (Bennis et al., 1995), (Brandrup et al., 1995), (O’Callaghan, 1996), (Reijnders, 1996), (Ruffing, 1998), (Ulhi et al., 1996) - and illustrated by successful company cases - see, e.g. (DeSimone et al., 1997), (Welford, 1994), (Winter, 1995), managers in enterprises will accept the goals of environmental management only if they are motivated enough. For the evaluation of environmentally oriented business decisions on business performance they can use the optimisation models which include the possibilities for an integrated approach to environmental protection. These possibilities (Brouwer, 1987), (Pregrad, Musil, 1996) are introduced in the second chapter.

Negative environmental impacts can be fundamentally reduced or even eliminated by changes being made to products. However, these changes are closely linked to changes in business processes, especially in the purchasing, production and selling processes. Since the desired changes in products can be achieved with changes in processes, products and business processes have an inseparable environmental impact. Therefore, the environmental factors are not only production policy and production assortment, but also the assortment of new processes.

In this paper, we deal with the key areas of marketing mix that can improve the environmental performance of business systems. A general optimisation model of the multiphase business process, which includes the possibilities for an integrated approach to environmental protection, is written in the third chapter.

Further, development and application possibilities of the presented model in environmentally oriented business decision-making are introduced.

Since one important aspect of eco-efficiency in practice is resource productivity - doing more with less (DeSimone et al., 1997), we also deal with resource efficiency. Using the presented optimisation model, some measures of resource efficiency are written in the fourth chapter.

2. POSSIBILITIES FOR AN INTEGRATED APPROACH TO ENVIRONMENTAL PROTECTION

2.1. Areas of marketing mix as environmental issues

According to the theory of the environmental marketing management, the product is the cornerstone of the marketing mix (Peattie, 1995) and the most important and decisive key element of the environmental management. Managers must evaluate the possibilities for the substitution of products. However, enterprises can improve their environmental performance by changes being made to existing products. Since environmentally friendly products are produced in environmentally friendly ways, managers must evaluate the possibilities for recycling, technology improvements and the substitution of technological procedures.

The environmental friendliness of the products is also determined by the environmentally friendly material choice, supplier choice and energy savings. The choice of material inputs into the production process should be assessed by using suggested checklists - see, e.g. (Peattie, 1995), (Welford, Gouldson, 1993), suitable for the considered production process. Further, managers of the production systems should treat suppliers at least as business opportunity groups or even as a part of their own environmental management system. First, the supply chain must be rearranged according to the results of the analysis of the suppliers' eco-performance. In purchasing, transportation and storing, management must focus on environmentally friendly materials. When the list of materials and their suppliers is made - according to the environmental and social criteria, the best combination of them can be selected using the optimisation model of the environmentally managed business process.

Another area of marketing mix - that is to be treated as an environmental issue - is addressed as transportation and distribution. When the idea of an environmentally sound strategy is adopted, this key area must be examined at the review stage and also re-examined by the environmental audit. Following

Welford and Gouldson (Welford, Gouldson, 1993), preference should be given to the transportation systems that have reduced environmental costs in terms of energy consumption and pollution. As transport systems should be as efficient as possible, the transportation problem can be included in the multiphase business process optimisation model. We could also include the inventory problem, but let us assume that there is no time lag between the purchase of the elements of the business process and their consumption in the production process. This assumption bases on the principles of just-in-time (JIT) management systems, which (among other benefits) cut down the need for storage since materials are purchased or generated in exact quantities and just at the same time they are needed. When taking into account other benefits of JIT - see, e.g. (Welford, Gouldson, 1993), (Kotler, 1998), we realise that JIT systems improve environmental performance. At the same time, they increase the business results of enterprises since the inventory costs do not arise.

2.2. Approaches to environmental management

Following Peattie (Peattie, 1995), the environmental impact of a tangible product is divided into product use, product disposal, production itself and the inputs of materials and energy into the production process. Treating the environmental activities as divided functions can not lead to global environmental protection and improvement. In literature - see, e.g. (Peattie, 1995), (Winter, 1995) - a holistic approach to environmental management is emphasised: a business should be managed as a total system, and not simply as a collection of functions or business units (Peattie, 1995). For example, materials of higher quality lead to less waste in the production process and often give more opportunities for waste recycling.

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 dealing with environmental problems (Beinat, 1997). To support the decomposed and the holistic decision-making, optimisation of the total multiphase business process is needed. Therefore, the possibilities for an integrated approach to environmental protection must be included in the general model of the total multiphase business process so that it can be applied as a scenario by the business process simulation for the evaluation of environmentally oriented business decisions on business performance.

3. OPTIMISATION MODEL OF THE ENVIRONMENTALLY ORIENTED BUSINESS PROCESS

3.1 The initial optimisation model

A general separable model of the business process (Meško, Meško, 1994) is constructed for a multiphase business process where production elements of the business process and phase products, which can also be purchased or sold, are processed into final products. Since in the production process the product of one production phase can enter as a production element into another production phase, we shall refer to production elements, phase products and final products as elements.

Let us consider the business process where primary and environmentally friendly products can be sold, phase products and useful waste can be purchased, sold or processed, whereas harmful waste is disposed of or given away. Further, the primary and environmentally friendly production elements, as well as the phase products along with the useful waste with the sources outside the production process can be purchased. If primary production elements and phase products are substituted with the environmentally friendly ones, they are assigned the new sources outside the production process or are treated as the new relevant elements. Semi-fixed costs can arise due to the sale of environmentally friendly products and phase products and harmful waste being given away, as well as due to the purchase of environmentally friendly phase products and production elements. Due to the consumption of irrelevant elements, the cost of the production activities can arise.

Some possibilities for an integrated approach to environmental protection can be included in the general separable model of the business process. The initial model is written by (1)-(4).

$$\max\left(\sum_{i \in Z} p_i(z_i) - \sum_{i \in Z} p_i(z_i) - \sum_{i \in Y} s_i(y_i) - \sum_{i \in Y} c_i(y_i) - \sum_j v_j(x_j)\right) \quad (1)$$

subject to non-negative decision variables z_i , y_i and x_j and to the constraints for relevant elements

$$e_i = \sum_{j \in R_i} r_{ij}(x_j) + y_i - \sum_{j \in Q_i} q_{ij}(x_j) - z_i \geq 0 \quad i \in E \quad (2)$$

and eventual market constraints

$$d_i \leq z_i \leq D_i \quad \text{for some } i \quad (3)$$

$$b_i \leq y_i \leq B_i \quad \text{for some } i \quad (4)$$

The symbols used in the model are described in the Appendix.

With the first sum in the objective function (1), the income from the sale of primary and environmentally friendly products, phase 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. The semi-fixed costs of the sale of the environmentally friendly final products and phase products, as well as the waste sale and disposal, expressed with the second sum in (1), are subtracted from the income. For example, the promotional cost of green promotions can be expressed with the second sum in (1). The variable costs that are caused by the purchase of the relevant elements are expressed with the third sum in (1). Also, the semi-fixed costs of the purchase of environmentally friendly elements of the business process and phase products, expressed with the fourth sum in (1), as well as with the fifth sum in (1) expressed other variable costs of production activities due to the consumption of irrelevant elements are subtracted from the income. Therefore, the costs of the irrelevant elements' consumption that arise due to the integrated environmental protection in the multiphase business process can be added to the purchasing costs or prime variable cost due to the consumption of the i -th element s_i . Further, they can be subtracted from the income from the sale of the i -th element p_i or are considered as the j -th production activity cost v_j . They can appear as the cost of collecting, sorting and rendering, the cost of recycling, as well as the cost of disposal (Brandrup et al., 1995).

For each relevant element, a material balance constraint (2) is needed. It assures that the sum of the processed and sold quantity does not exceed the sum of the purchased and produced quantity of the i -th element. Market limits and capacities of production means give rise to (3) and (4).

When the functions p_i , s_i , v_j , r_{ij} and q_{ij} are linear, model (1)-(4) can be written as a linear optimisation model with the objective function (1), without the second and the fourth sum. With the objective function, the contribution is expressed. Model (1)-(4), where g_i and c_i are semi-fixed costs and the functions p_i , s_i , v_j , r_{ij} and q_{ij} are piecewise linear, can be written as the linear mixed integer model. With the objective function, the contribution, decreased by semi-fixed costs, is expressed. Using zero-one variables, the possibilities of

integrated environmental protection in the business process optimisation can be decomposed according to the type of the considered element (Čančer, 1997).

3.2. Development and application possibilities

The presented model (1)-(4) is suitable for application as one of the tools in current environmentally oriented business decision-making.

Multiple criteria are suitable to be considered for environmental management (Bogetoft, Pruzan, 1991), (Beinat, 1997). Multiple objective optimisation models are applied especially at the macro level with more decision-makers. In enterprises, such models are applied for strategical and tactical decision-making, for example about the investments into environmental improvement (Fussler, James, 1996). For current business decision-making, the results of optimisation must be provided quickly, but choosing the compromise solution may be too lasting. Further, the decisions of more decision-makers are often inconsistent. Therefore, it is suitable for decision-makers to express their preferences beforehand and in a meaningful way.

The presented model can be completed in the model for goal optimisation of the environmentally managed business process. Goals of the integrated environmental protection (e. g. the meeting of demand for an environmentally friendly product, phase product or for waste, as well as waste management decisions) can be included in a model of the environmentally managed business process.

Let us complete model (1)-(4) in the basic model for goal optimisation of the environmentally oriented business process:

$$\max\left(\sum_{i \in Z} p_i(z_i) - \sum_{i \in Z} g_i(z_i) - \sum_{i \in Y} s_i(y_i) - \sum_{i \in Y} c_i(y_i) - \sum_j v_j(x_j) - \sum_{i \in C} \zeta_i(\xi_i) - \sum_{i \in C} \tau_i(\omega_i)\right) \quad (5)$$

subject to non-negative decision variables z_i, y_i, x_j, ξ_i and ω_i , the constraints for relevant elements (2), eventual market constraints (3) and (4), and to

$$\xi_i - \omega_i = \chi_i - \sum_j a_{ij}(x_j) \quad i \in C \quad (6)$$

where the i -th goal is realised when

$$\sum_j a_{ij}(x_j) = \chi_i \quad i \in C \quad (7)$$

The symbols used in the model are described in the Appendix.

When the functions p_i , s_i , v_j , r_{ij} , q_{ij} , as well as ζ_i , τ_i and a_{ij} are linear or piecewise linear, the presented model can be written as the linear mixed integer optimisation model. With the objective function, the contribution, decreased by the penalties of the deviations from goals and by semi-fixed costs, is expressed. The obtained model for goal optimisation can also be used for the evaluation of other goals of environmental management in the enterprise. Air pollution, water pollution and waste on land, as well as the penalties for pollution offences can be included in the presented model.

To attain the first business impression about the investment favourableness into clean technology, the optimisation model (1)-(4) can be completed in the fractional optimisation model. This model can be transformed by Charnes-Cooper transformation (Charnes, Cooper, 1962) and the linearisation of the products between zero-one variables and the continuous variable into the linear mixed integer optimisation model (Meško, Meško, 1994). With the objective function, the increase of the contribution, decreased by semi-fixed costs, per invested monetary unit is expressed. Managers can use the results of the model, with included particularities and goals of environmental management, as the first sign about the investment favourableness. For investment decision-making not only other modern investment decision-making methods - see, e.g. (Babić, Tomić-Plazibat, 1999), (Haugen, 1990), (Henig, Katz, 1996), (Njavro, Barac, 1999), (Northcott, 1992) - must be applied, but also environmental and social goals must be considered (Pregrad, Musil, 1996).

The presented method for environmentally oriented business decision-making by simulation (Szymankiewicz et al., 1988), using the presented optimisation model as a scenario (Meško et al., 1995) of the business process, has already been verified and applied in medium-sized enterprises in the processing industry with multiphase business processes (Čančer, 1998). This model can also be applied in widespread ramified business processes in large enterprises.

Transportation and distribution are not only to be treated as serious environmental issues, but can also negatively affect business results. Using the optimisation model (1)-(4), the transportation cost can be added to the

purchasing costs of the considered element or subtracted from the income from the sale of the considered element. When particular attention is given to transportation, the transportation cost can be included in the objective function in particular sums. Let us assume that an enterprise is made up of more production units where a similar production program could be implemented. They are located at different locations. The optimisation model of the multiphase business process can be applied to support decisions about choosing the production unit or the combination of production units, which ever is most appropriate for the particular production process performing. A fictitious element belongs to each source of the considered element. Similarly, a fictitious element belongs also to each production unit that processes the considered element. The transportation cost from the k -th source to the l -th production unit is written as $t_{kl}(x_{kl})$, where x_{kl} is the quantity of the considered element of the business process, transported from the k -th source to the l -th production unit, whereas t_{kl} is the transport cost per unit of the element transported. In the objective function (1), the double sum $\sum_{k \in K} \sum_{l \in L} t_{kl}(x_{kl})$, where K is the index

set of sources and L is the index set of production units, is subtracted. For each fictitious element that is to be transported from the k -th element's source to l production units, a material balance constraint (8) is constructed:

$$e_k = y_k - \sum_l x_{kl} \geq 0 \quad k \in K \quad K \subset E \quad (8)$$

It assures that the quantity of the k -th element, transported from the element's source to the production units that process this element, can not exceed the source capacity of this element. For each element that is transported to the certain production unit from different sources, a material balance constraint (9) is constructed:

$$e_l = \sum_k x_{kl} - \sum_j r_{lj}(x_j) \geq 0 \quad l \in L \quad L \subset E \quad (9)$$

It assures that in the l -th production unit, the processed quantity of the considered element can not exceed the quantity of the considered element transported to this production unit from different sources. If the model (1)-(4) is linear prior to including the transportation problem, a linear programming problem is obtained when the function t_{kl} is linear. When the function t_{kl} is piecewise linear, it can be included in the linear mixed integer optimisation model. In the linear mixed integer optimisation model, new sources and

production units can be included; moreover, semi-fixed costs due to the transport can be considered by introducing zero-one variables.

When the optimisation model is completed by the transportation problem, more economic activities, e.g. agriculture as the supplier and industry as the customer, can be connected as well. We think that the obtained model is appropriate to apply to the life-cycle analysis (LCA) of the product's environmental impact in all phases of the life cycle, i.e. from cradle to grave.

4. RESOURCE EFFICIENCY

To support the evaluation of the consequences of environmentally oriented business decisions on business results, as well as to give the decision-makers an insight into the consequences of their decisions on the environment, comprehensible and useful tools should be generated. The concept of eco-efficiency implies that we have to make optimal use of both ecological and economic resources (DeSimone et al., 1997). For the preparation and making of environmentally oriented business decisions, eco-efficiency measures should include the categories that are already known to the decision-makers and they should be integrated in the existent decision-support system.

The environmental impact of a particular production process relates to the nature of technology being used, and to the safety and efficiency with which it is used. The green challenge has mainly focused on unwanted outputs in terms of pollution and waste (Peattie, 1995). Another important measure in terms of environmental performance is the resource efficiency of the production system (Peattie, 1995), which can be written as the ratio between economically valuable outputs, and material and energy inputs.

Once the model of the environmentally oriented business process (1)-(4) is constructed and solved by one of the appropriate computer programs, it contains the information for the measurement of the resource efficiency of the production system. Following the optimisation model (1)-(4), completed by the transportation problem, the overall resource efficiency measure of the environmentally oriented business process can be written as follows:

$$\frac{\sum_{i \in Z} p_i(z_i)}{\sum_{i \in Z} g_i(z_i) + \sum_{i \in Y} s_i(y_i) + \sum_{i \in Y} c_i(y_i) + \sum_j v_j(x_j) + \sum_{k \in K} \sum_{l \in L} t_{kl}(x_{kl})} \quad (10)$$

Using (10), we can write the resource efficiency measures where a denominator is constructed for a particular business process:

- Following the initial optimisation model (1)-(4), we can consider only the second and the fourth sum of the denominator in (10). This resource efficiency measure can be applied in a particular production unit, as well as in the enterprise, which is made up of more production units and taken as a holistic system.
- When a transportation problem is included in the multiphase business process, we consider the second, the fourth and the last sum of the denominator in (10). This measure can usefully be applied in enterprises that are made up of more production units and are taken as holistic systems, as well as in the production units that purchase the elements of the business process from more dislocated suppliers and devote special attention to the transportation cost; in the latest case index l is not needed.
- We can also develop a measure of efficiency of an environmentally oriented business process by considering the first four sums of the denominator in (10).

When the results of the simulations of the environmentally oriented business process are obtained by using the optimisation model described in the third chapter, other potential indicators of the production process efficiency - like materials efficiency, materials quotients, within company recycling efficiency, energy efficiency, energy coefficient (Reijnders, 1996), eco-productivity indices, resource productivity index, eco-points, eco-compass (DeSimone et al., 1997) - can be developed in co-operation between experts of different professions, considering the characteristics of a particular system.

We can include the efficiency measure (10) or one of its versions in the optimisation model of the business process (1)-(4) as the constraint. We obtain the fractional optimisation model, which can be transformed in the linear mixed integer one, as described in the third chapter, and solved by one of the available computer programs.

5. CONCLUSION

The method for environmentally oriented business decision-making by simulation and by using the presented optimisation model as a scenario has already been applied (Čančer, 1998) in the processing industry.

The presented model is suitable for application in small and medium-sized, as well as in larger enterprises. Application of the presented method can show

managers the possibilities for income increasing and costs decreasing, caused by decisions for environmental protection and improvement in enterprises, even in the short run. Furthermore, the model can be completed in the model for goal optimisation or partly included as one of the criteria in one of the appropriate multiple objective optimisation models. The presented measures should be included as indicators into a common framework within which managers can apply them to assess and evaluate progress towards eco-efficiency at a business level and towards sustainability at a national level.

The optimisation model of the environmentally managed business process presented in the paper can be applied as a scenario for its verification and for the evaluation of business decisions that consider environmental protection on business performance. It can be applied as a tool for business decision-making about some fields of integrated environmental protection in enterprises. However, for complete integrated environmental protection in enterprises, environmental protection must be included at all levels and in all functional areas in enterprises (Winter, 1995). Further, the appropriate informational and control system must be built and co-operation between experts of different professions must be enabled.

REFERENCES:

1. Babić, Z., Tomić-Plazibat, N. (1999), Making investment decisions with multicriterial analysis and zero-one programming, *Management, Journal of Contemporary Management Issues*, Vol. 4, No. 1-2, pp. 167-178.
2. Beinat, E. (1997), *Value Functions for Environmental Management*, Kluwer Academic Publishers, Dordrecht, Boston, London.
3. Bennis, W., Parikh, J., Lessem, R. (1995), *Beyond leadership: balancing economics, ethics and ecology (Developmental management)*, Blackwell Publishers Inc., Cambridge - USA, Oxford - UK.
4. Bogetoft, P., Pruzan, P. (1991), *Planning with Multiple Criteria*, Elsevier Science Publishers B. V., Amsterdam etc.
5. Brandrup, J., Bittner, M., Michaeli, W., Menges, G. (1995), *Die Wiederverwertung von Kunststoffen*. Carl Hanser Verlag, München - Wien.
6. Brouwer, F. (1987), *Integrated Environmental Modelling: Design and Tools*, Kluwer, Dordrecht etc.
7. Charnes, A., Cooper, W. W. (1962), *Programming with Linear Fractional Functionals*, *Naval Research Logistic Quarterly*, No. 6, pp. 181-186.
8. Čančer, V. (1997), *Business Process Optimisation Model Including the Integrated Environmental Protection*, in: Rupnik, V., Zadnik Stirn, L., Drobne, S. (Eds.), *Proceedings of the 4th International Symposium on Operational Research in Slovenia SOR '97*, Preddvor, Slovenian Society Informatika, Section for Operational Research, Ljubljana, pp. 171-176.

9. Čančer, V. (1998), Simuliranje izvajanja okoljsko upravljanega poslovnega procesa z optimizacijskim modelom (Simulation of the Environmentally Managed Business Process with Optimisation Model), Doctoral Dissertation, Faculty of Economics and Business, Maribor.
10. De Haas, J. P. (1989), Management-Philosophie im Spannungsfeld zwischen Ökologie und Ökonomie, Verlag Josef Eul, Köln.
11. DeSimone, L. D., Popoff, F. with the World Business Council for Sustainable Development (1997), Eco-efficiency: the business link to sustainable development, The MIT Press, Cambridge - Massachusetts, London - England.
12. Fussler, C., James, P. (1996), Driving Eco-Innovation: A breakthrough discipline for innovation and sustainability, Pitman Publishing, London etc.
13. Haugen, R. A. (1990), Modern Investment Theory - 2nd Edition, Prentice Hall, Englewood Cliffs, New Jersey.
14. Henig, I. M., Katz, H. (1996), R & D Project Selection: A Decision Process Approach, Journal of Multiple-Criteria Decision Analysis, Vol. 5, pp. 169-177.
15. Kotler, Ph. (1998), Marketing Management - 2nd Edition, Slovenska knjiga, Ljubljana.
16. Meško, I., Čančer, V., Meško, T. (1995), Decision Support Scenario of the Multiphase Production Process, in: Proceedings of the 2nd international conference Design to Manufacture in Modern Industry, Maribor: Faculty of Mechanical Engineering, part 1; pp. 309-318.
17. Meško, I., Meško, T. (1994), Multiphase Business Process Optimization, Belgian Journal of Operations Research, Statistics and Computer Science, Vol. 34, No. 4, pp. 63-71.
18. Njavro, Đ., Barac, Z. (1999), Institutional Investors; Procedures in Selection of Optimal Investment Combination, Management, Journal of Contemporary Management Issues, Vol. 4, No. 1-2, pp. 49 - 80.
19. Northcott, D. (1992), Capital Investment Decision-Making, Academic Press, London, etc.
20. O'Callaghan, P. W. (1996), Integrated Environmental Management Handbook, John Wiley & Sons Ltd., Chichester etc.
21. Peattie, K. (1995), Environmental Marketing Management, Pitman Publishing, London.
22. Pregrad, B., Musil, V. (1996), Technology and Integrated Environment Protection, in: Szafran, M. M., Koziol, L. and Malecka M., Quality for European Integration, University of Economics, Poznan, pp. 199-202.
23. Reijnders, L. (1996), Environmentally Improved Production Processes and Products: An introduction, Kluwer Academic Publishers, Dordrecht.
24. Ruffing, K. G. (1998), Sustainable consumption and production, UNEP Industry and Environment Review, Vol. 21, No. 4, pp. 12-15.
25. Szymankiewicz, J., McDonald, J., Turner, K. (1988), Solving Business Problems by Simulation, McGraw-Hill Book Company, London.
26. The Bruntland Report, World Commission on Environment and Development (1987), Our Common Future, Oxford University Press, Oxford.

27. Ulhoi, J. P., Madsen, H., Rikhardsson, P. M. (1996), Training in Environmental Management - Industry and Sustainability, Part 1: Corporate Environmental and Resource Management and Educational Requirements, European Foundation for the Improvement of Living and Working Conditions. Loughlinstown, Dublin.
28. Welford, R., Gouldson, A. (1993), Environmental Management & Business Strategy, Pitman Publishing, London.
29. Welford, R. (1994), Cases in Environmental Management and Business Strategy, Pitman Publishing, London.
30. Winter, G. (1995), Blueprint for Green Management: Creating Your Company's Own Environmental Action Plan, McGraw-Hill International (UK) Ltd., London.

APPENDIX:

The description of the symbols used in (1)-(10) is as follows:

- Z - index set of the relevant elements with the customers outside the business process;
- Y - index set of the relevant elements with the sources outside the business process;
- E - index set of the relevant elements;
- R_i - index set of the production activities producing the i -th element;
- Q_i - index set of the production activities processing the i -th element;
- $p_i: \mathfrak{R} \rightarrow \mathfrak{R}$ - 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;
- z_i - quantity of the i -th element that is sold or disposed of;
- $g_i: \mathfrak{R} \rightarrow \mathfrak{R}$ - semi-fixed costs due to the sale or disposal of the i -th element;
- $s_i: \mathfrak{R} \rightarrow \mathfrak{R}$ - purchasing costs or prime variable cost due to the consumption of the i -th element;
- y_i - purchased quantity of the i -th element;
- $c_i: \mathfrak{R} \rightarrow \mathfrak{R}$ - semi-fixed costs due to the purchase of the i -th element;
- $v_j: \mathfrak{R} \rightarrow \mathfrak{R}$ - variable costs of the j -th production activity due to the consumption of irrelevant elements;
- x_j - quantity of the j -th production activity;
- e_i - unallocated quantity of the i -th element;
- $r_{ij}: \mathfrak{R} \rightarrow \mathfrak{R}$ - quantity of the i -th element produced by the j -th production activity;
- $q_{ij}: \mathfrak{R} \rightarrow \mathfrak{R}$ - quantity of the i -th element processed by the j -th production activity;
- d_i - minimal quantity of the i -th element that has to be sold;
- D_i - maximal quantity of the i -th element that can be sold;

- b_i - minimal quantity of the i -th element that has to be purchased;
- B_i - maximal quantity of the i -th element that can be purchased;
- C - index set of goals;
- $\zeta_i: \mathfrak{R} \rightarrow \mathfrak{R}$ - penalties of the deviations from the i -th goal when $\xi_i > 0$;
- $\tau_i: \mathfrak{R} \rightarrow \mathfrak{R}$ - penalties of the deviations from the i -th goal when $\omega_i > 0$;
- ξ_i - deviation from the i -th goal when in (11) the right side is bigger than the left side;
- ω_i - deviation from the i -th goal when in (11) the right side is lower than the left side;
- χ_i - the i -th goal level;
- $a_{ij}: \mathfrak{R} \rightarrow \mathfrak{R}$ - linear or piecewise linear function x_j for the i -th goal expression;
- $t_{kl}: \mathfrak{R} \rightarrow \mathfrak{R}$ - transportation cost from the k -th source to the l -th production unit;
- K - index set of sources in transportation problem;
- L - index set of production units in transportation problem.

ZAŠTITA OKOLIŠA U UPRAVLJANJU POSLOVNIM PROCESIMA

Sažetak

Pošto će donositelji poslovnih odluka prihvatiti ciljeve zaštite okoliša tek ukoliko su za to dovoljno motivirani, u tu je svrhu potrebno razviti sveobuhvatna i korisna oruđa za potporu poslovnog odlučivanja orijentiranog prema zaštiti okoliša. Stoga je u ovom radu predstavljen opći model za optimizaciju višefaznog poslovnog procesa. On uključuje i mogućnost integriranog pristupa zaštiti okoliša, tako da se može koristiti i kao scenario u simulaciji poslovnih procesa, orijentiranoj na procjenu "ekološki svjesnih" poslovnih odluka na rezultate poduzeća. U radu se raspravlja i o mogućnostima daljnjeg razvoja i primjene predstavljenog modela, te prezentiraju mjere efikasnosti primjene resursa razvijene na temelju spomenutog modela.