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Izvorni znanstveni članak

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ANALYSIS PROCEDURE FOR ENVIRONMENTALLY ORIENTED BUSINESS DECISION-MAKING

In this article we present the analysis procedure for environmentally oriented business decision-making in business processes. It is based on simulation with optimisation models that are used as scenarios in current decision-making. The particularities that menace successful application of direct sensitivity analysis are introduced. The decision-making method is presented with a practical case from the Slovene company.

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INTRODUCTION

In this article we present the method for environmentally oriented business decision-making that includes the preparation of business decisions about some fields of environmental assessment and integrated environmental protection. Since the presented method is based on simulation with scenario analysis, the general optimisation model that is used as a scenario in environmentally oriented business decision-making is presented as well. The analysis tools for the preparation of environmentally oriented business decisions should include the categories that are already known to decision-makers. For that reason, we introduce a resource efficiency measure as one of the main eco-efficiency measures by using the described optimisation model. However, users should be aware of the particularities that menace successful application of the optimal values printed in computer solution reports. They can also consider the research results about these values that are presented in this article.

The decision-making method is introduced with a practical case from the Slovene company Termoplast. Some examples in which scenario analysis and business process simulation are more appropriate to apply than direct sensitivity analysis, are presented as well.

OPTIMISATION OF ENVIRONMENTALLY MANAGED BUSINESS PROCESS

To support decomposed and 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. This model can be applied as a scenario by the business process simulation for the evaluation of environmentally oriented business decisions on business performance and on environment.

The general model 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. For each relevant element a material balance constraint is needed:

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

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

$$f_i \leq z_i \leq F_i \qquad \text{for some } i$$

$$b_i \leq y_i \leq B_i \qquad \text{for some } i$$

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

$$\sum_l \kappa_l \lambda_l \leq K$$

With the objective function, the contribution

$$\sum_{i \in Z} p_i(z_i) - \sum_{i \in Z} g_i(z_i) - \sum_{i \in Y} s_i(y_i) - \sum_{i \in Y} c_i(y_i) - \sum_j v_j(x_j) \qquad (2)$$

or its increase per monetary unit

$$\frac{I - \sum_l \alpha_l \lambda_l - z_0}{\sum_l \kappa_l \lambda_l} \qquad (3)$$

or the resource efficiency measure

$$\frac{\sum_{i \in Z} p_i(z_i)}{\sum_{i \in Z} g_i(z_i) + \sum_{i \in Y} s_i(y_i) + \sum_{i \in Y} c_i(y_i) + \sum_j v_j(x_j)} \qquad (4)$$

can be expressed. (4) can also be included as a constraint in the optimisation model of the environmentally oriented business process:

$$\frac{\sum_{i \in Z} p_i(z_i)}{\sum_{i \in Z} g_i(z_i) + \sum_{i \in Y} s_i(y_i) + \sum_{i \in Y} c_i(y_i) + \sum_j v_j(x_j)} \geq \mathrm{P} \qquad (5)$$

The symbols used in the model are described in Appendix.

When the functions p_i, s_i, v_j, r_{ij} and q_{ij} are linear, the model can be written as a linear optimisation model with the objective function (2), without the second and the fourth sum. The model 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. When the functions (3), (4) and (5) are included in the model, we obtain the fractional optimisation model. This model can be transformed into the linear mixed integer optimisation model.

Some possibilities for an integrated approach to environmental protection and improvement can be included in the general model of the business process: substitutions of raw materials, suppliers, phase products and final products as well as recycling processes and technology improvements; special attention is given to the waste - by products of the production process, the waste created by consumers after the use of products and the packaging waste.

SHADOW PRICE ANALYSIS, SIMULATION AND SCENARIO ANALYSIS

A linear, linear mixed integer or fractional optimisation model of the business process can be applied as a scenario for its verification and for the evaluation of business decisions on business performance. For both purposes, shadow price analysis is usually used.

In this article, the shadow price is defined as the change of the optimal objective function value due to the change of the available quantity of the considered element per unit. The optimal value of the dual variable that belongs to the relevant element's balance constraint (1) is usually interpreted as the shadow price of this element. However, circumspection is needed when using this interpretation for the following reasons:

in the linear model results, the optimal values of dual variables, produced by adequate computer codes, can not be applied directly for sensitivity analysis because of the degeneration; further, the right-hand side ranges must be paid attention to;

the model transformation and the value changes of zero-one variables can menace the above interpretation in the linear mixed integer model results.

The optimal values of dual variables can therefore be used as the signs in decision-making; the consequences of business decisions must be verified by a new simulation with the optimisation model as a business process scenario.

The simulation results about the optimal values of dual variables can usefully be applied in business decision-making at micro level. Performing simulation with scenario analysis, we can analyse the changes in these values when the parameters of the optimisation model are random variables and when decision-makers change their preferences.

A PRACTICAL CASE

The method for environmentally oriented business decision-making by simulation and by using the optimisation model as a scenario has already been applied in the processing industry. In the Slovene company Termoplast packaging for diary products is produced. The materials used are polypropylene (PP) which is generally considered environmentally more friendly, and polystyrene (PS) which is generally considered environmentally less friendly.

We summarised the results of our work in three simulations in order to illustrate the decision-making method. Simulation 1 gives the optimal business process realisation for the initial business process. Simulation 2 includes some possibilities for an integrated approach to environmental management. Simulation 3 is completed by investment possibilities into the capacities for PP and PS final products' production and by substitution of production processes.

Simulation 1: the initial business process

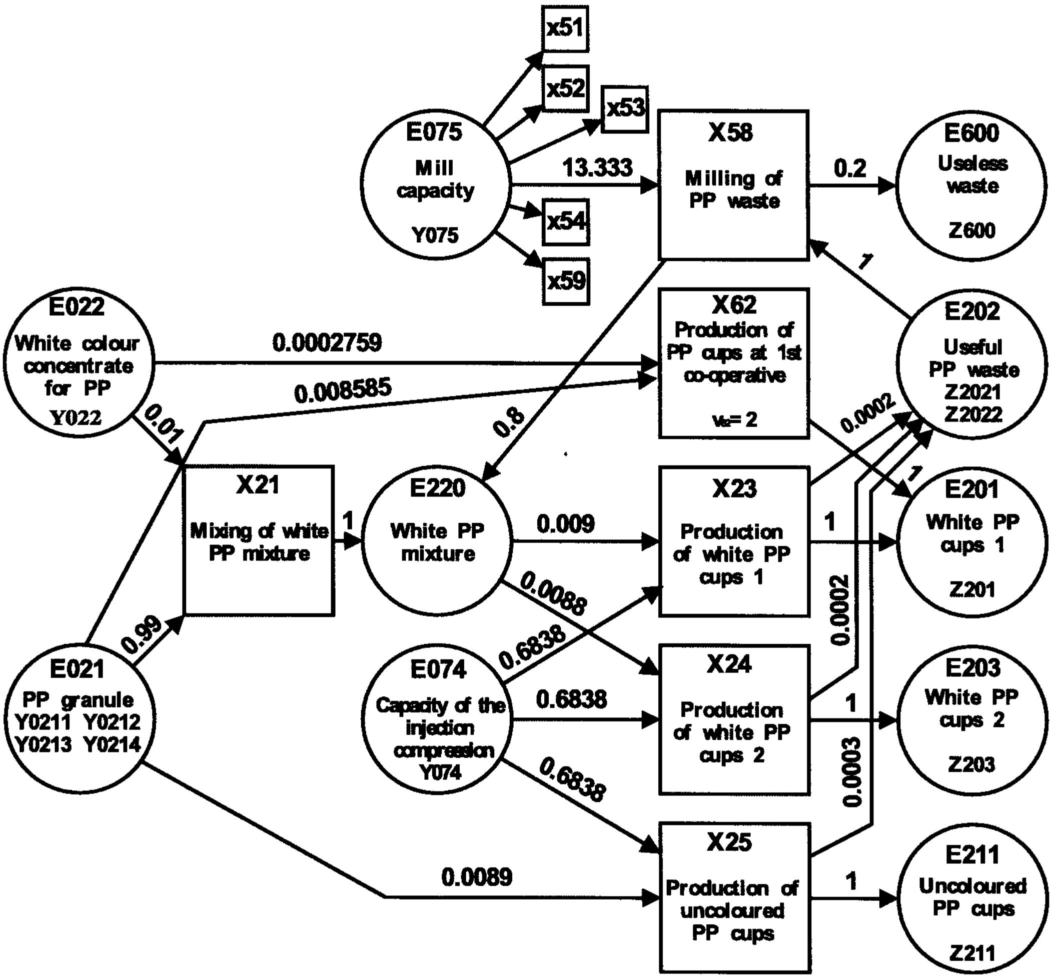
On initiating the optimisation of the business process into the business system, we made a list of all important elements. The data for the elements "PP granule", "White PP cups 1" and "Useful PP waste" are presented in Table 1. In simulation 1 we obtained 55 relevant

Table 1: Some examples of the elements and the market data

Element			Source/Customer			
Symbol	Name	Unit	Symbol	Price	Minimal quantity	Maximal quantity
E021	PP granule	t	Y0211	131		0.00625
			Y0212	140.6		2.025
			Y0213	133		0.042
			Y0214	144.4	0.5	
E201	White PP cups 1	1000 pieces	Z201	5.77		48.5
E202	Useful PP waste	t	Z2021	70		0.1
			Z2022	12.5		

We also constructed the graph of this business process. In simulation 1 we obtained 45 production activities. We had to include different possibilities for particular parts of the business process. In Figure 1 we present only a part of the production process to introduce the PP cups production.

Figure 1: A part of the business process graph



Element and market data as well as technological data of the considered business process were inputted with an appropriate computer program that constructs also the linear model 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. Some results of simulation 1 are written in Table 4.

When the model is verified, it can be used as a scenario of the business process for the evaluation of environmentally oriented business decisions on business performance.

Simulation 2: environmentally oriented business decisions

Environmental degradation is decreasing with waste recycling that is included in the production process in Termoplast. In Termoplast a closed water system is constructed, so that negative effects of water consumption in PP cups production and degradation on the environment as well as on business results can be neglected. We can conclude that - put together - the effect of the substitution of PS products with PP ones on the environment is favourable.

Simulation 2 includes the substitution of final PP and PS products, marketing research for environmentally friendly materials and products, the substitution of PP and PS materials and minimal quantity of the environmentally friendly material that has to be purchased. Considering these possibilities for integrated environmental protection, the linear mixed integer optimisation model of the environmentally oriented multiphase business process was written.

From the solution, obtained with an appropriate computer program, we can conclude to which customers the sale of PS cups must be substituted with the sale of PP cups; the quantities of the cups sale per type to achieve the optimal business result; that we have to perform market research for PP granule; the optimal purchase quantities of PP granule; that we have to purchase even more than the obligatory quantity of PP granule and so we can also purchase PS in the future; the optimal quantities of wastes that must be processed, sold or disposed of; the optimal quantities of production activities; for the elements that can be produced by co-operatives, the quantities that are to be produced by the co-operatives and the quantities that are to be produced in the enterprise; that the capacities of the machines are completely exploited. Further, the shadow prices belonging to the "Capacity of the machine for injection compression" and the "Vacuum-machine capacity" are very high; the belonging positive values of the opportunity costs can be used as the signs for the investment decision-making.

The optimal values of the criteria in this simulation are presented in Table 4.

Let us present some examples, in which scenario analysis and simulation are preferred instead of direct shadow price analysis.

Element E021 "PP granule" can be purchased at different prices from four sources; three of them are limited. When we have more bounded sources for an element, the right-hand side ranges are to be paid attention to: these ranges can be very short, depending on the element's source capacities and the optimal exploitation of these capacities.

The results in Table 2 show that the standard deviation of the optimal values of the dual variable belonging to E201 d_{201} and the belonging coefficient of variation in the linear mixed integer optimisation model is larger than in the linear one. We can conclude that the changes of the optimal values of zero-one variables in the linear mixed integer optimisation model increase the variability of the optimal values of dual variables.

Table 2: The variability of the optimal value of the dual variable d_{201} in the linear and the linear mixed integer optimisation model

Selling price for E201 p_{201}~N(3.5,1)	Standard deviation of the optimal values of the dual variable d_{201}	Coefficient of variation of the optimal values of the dual variable d_{201}
LINEAR MIXED INTEGER MODEL	0.7525	34.66 %
LINEAR MODEL	0.3830	14.07 %

Simulation 3: investment decisions

We completed the simulation of the business process with the investment in the capacity of the additional vacuum-machine (for the PS cups production) or in the capacity of the machine for injection compression (for the PP cups production). With the objective function (3) we obtained the fractional optimisation model. Considering the optimal solution we have to invest into the capacities of the machine for injection compression (λ_{074}=1). The optimal values of the criteria in this simulation are presented in Table 4. Again, with the optimal solution we can prepare the environmentally oriented production and market decisions as described above.

In simulation 3 let us include the decision-maker's preference to invest into the vacuum-machine capacity (λ_{073}=1). Comparing the results in Table 3 we can conclude that the decision maker's preference to invest into the investment project that is not optimal regarding the optimal solution, yields a lower optimal objective function's value and a lower standard deviation of its values than the optimal investment project. Further, this decision effects also the lower variability of the shadow price for E002. Namely, the vacuum-machine capacity is exploited in the same production activities as the element E002 is consumed.

Table 3: The variability of the optimal objective function values and the optimal values of the dual variable d_{002} when investments are included in the model

Upper bound of the source for E002 $\tilde{B}^{s}_{0023}$ čN(35, 10)	Optimal objective function value	Standard deviation of the optimal objective function values	Standard deviation of the optimal values of the dual variable d_{002}	Coefficient of variation of the optimal values of the dual variable d_{002}
Optimal solution: λ_{074}=1	0.053	0.01140	0.001127	11.5 %
Preference: λ_{073}=1	0.04209	0.007683	0.00007897	2.28 %

Table 4: Some measures for environmentally oriented business decision-making

	Simulation 1	Simulation 2	Simulation 3
Contribution	13716 m.u.	15285 m.u.	39519 m.u.
Contribution, decreased by semi fixed costs	-	15240 m.u.	39383 m.u.
Increase of the contribution decreased by semi-fixed costs per invested monetary unit	-	-	0.053
Resource efficiency: income per variable costs	2.36	3.12	2.38
Resource efficiency: income per the sum of variable and semi-fixed costs	-	3.10	2.36
Cost of the waste disposal per contribution	0.0018	0.0016	0.0006

Some measures of the consequences of the simulated business decisions on business performance and on environment are presented in Table 4. We can conclude that environmentally oriented business decisions in simulations 2 and 3 cause higher contribution (better business performance), higher values of the resource efficiency measures and lower values of the within company recycling efficiency (improved environmental impact), and therefore better eco-efficiency.

CONCLUSION

The described model is suitable for application as one of the tools in current environmentally oriented business decision-making. The effects of the business decisions on business performance must be verified by new simulation using the optimisation model as a scenario of the business process.

The model enables the decision-makers in enterprises to consider different fields of integrated environmental protection and to treat the environmental activities as connected functions. For complete integrated environmental protection in enterprises, environmental protection must be included at all levels and in all functional areas in enterprises.

LITERATURE:

1. Aucamp, D.C. and D.I. Steinberg, The Computation of Shadow Prices in Linear Programming, J. Opl. Res. Soc., 33 (1982) pp. 557-565.

2. Charnes, A. and W.W. Cooper, Programming with Linear Fractional Functionals, Naval Research Logistic Quarterly, 6 (1962), pp. 181-186.

3. Čančer, V., Business Process Optimisation Model Including the Integrated Environmental Protection, in: Proceedings of the 4th International Symposium on Operational Research in Slovenia SOR '97, Preddvor, Slovenian Society Informatika, Section for Operational Research, Ljubljana, 1997, pp. 171-176.

4. Horst, R., On the Interpretation of Optimal Dual Solutions in Convex Programming, J. Opl. Res. Soc. 35, 4 (1984) pp. 327-335.

5. Meško, I., Čančer, V. and T. Meško, Decision Support Scenario of the Multiphase Production Process, in: Proceedings of the 2nd International Conference Design to Manufacture in Modern Industry, Faculty of Mechanical Engineering, Maribor, 1995, part 1, pp. 309-318.

6. Watson, C.J., Billingsley, P., Croft, D.J. and D.V. Huntsberger, Statistics for Management and Economics, Allyn and Bacon, Massachusetts, 1990.

7. Welford, R. and A. Gouldson, Environmental Management & Business Strategy, Pitman Publishing, London, 1993.

APPENDIX

The description of the symbols 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: $\Re \to \Re$ - 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;

z_i - quantity of the i-th element that is sold or disposed of;

g_i: $\Re \to \Re$ - semi-fixed costs due to the sale or disposal of the i-th element;

s_i: $\Re \to \Re$ - 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: $\Re \to \Re$ - semi-fixed costs due to the purchase of the i-th element;

v_j: $\Re \to \Re$ - 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}: $\Re \to \Re$ - quantity of the i-th element produced by the j-th production activity;

q_{ij}: $\Re \to \Re$ - quantity of the i-th element processed by the j-th production activity;

f_i - minimal quantity of the i-th element that has to be sold;

F_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;

α_l - semi-fixed costs of the l-th investment;

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;

k_l - capital for the l-th investment;

K - maximal available capital for all investments;

I - maximal contribution decreased by the semi-fixed costs of the environmental improvement after the realisation of investments;

z_0 - maximal contribution decreased by the semi-fixed costs of the environmental improvement before the realisation of investments;

P - minimal value of the resource efficiency measure that has to be achieved.

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Summary

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