Application of operational analysis methods in alternative energy sources

Marcela Pavlíčková[1] *and* ***Katarína Teplická***[2]

This contribution presents decisions of exploitation of quantitative methods of operational analysis in the area utilizing alternative power source. Description of quantitative models make possible to optimalize processes of food-supply, service and renewal in business translation focus utilizing of alternative power source. They show to possibilities to optimalize of supply, process services and of the process renewal of machines. In this contribution are used scientific mathematical models – model optimally supplies, model Bayesov principle optimum and model way reproduction. Following applications of this models we can support decisions of processes and to optimalize parameters of process.

Keywords: *model, quantitative methods, operational analysis, optimalization, profit*

Introduction

Quantitative methods are now an important tool in management of each company when deciding in terms of risk, uncertainty or certainty. (Ivančová and Brezina 1997). Choosing a suitable alternative solutions to the economic problem and its application in practice requires knowledge of the risk and the usefulness of the chosen alternative for the conditions of the process in the company. Mathematical modeling is now supporting managers by decision making, interpretation of reality via mathematical models and its economical interpretation (Ivančová et al. 2007).

In this paper we discuss optimization of processes of supply, operation and recovery in the use of alternative energy sources with the focus on the supply of pellets, construction of storage area for wood chips and the turbogenerator reconstruction. Optimization of business processes is an important part of the continuous improvement of business processes. Through optimal process parameters it is possible to reduce the company costs, leading to the elimination of waste of resources and eliminating downtime. The use of quantitative models in practice and their application in decision-making processes and management is now essential, nevertheless companies lack the human potential and know-how to handle the issue of mathematical modeling in business processes (Čuchranová and Vodzinský 2003).

Mathematical modeling is useful in various sectors of national economy, it is used in military, aerospace industry, transportation, information technology and is also applied in the use of alternative energy sources.

Project methodology - Quantitative models of operational analysis

Use of different mathematical models to solve the optimization of business processes requires knowing mathematical apparatus and modeling. To solve problems in the present contribution we will discuss three types of models that fall within the area of operational analysis. Operational analysis is a scientific discipline that deals with the optimization of business and other processes through the use of mathematical models and modeling (Gros 2003).

For pellets retail inventory optimization problem, we will use a mathematical model of the optimal size of the delivery, which represents the single-product, single-store inventory model with limitless shelf life. It is a stationary dynamic model, which is cost-oriented, ie. the objective function has the cost character. The aim of the model is to optimize the basic parameters of the model, ie. inventory order quantity Q, and the level of ordering inventory r, taking into account the economic criterion, the total annual cost of the supply process, which must be minimized.

$$N_C = \frac{\lambda}{Q_{opt}} N_O + \frac{Q_{opt}}{2} N_S + \lambda O_C \quad [€] \tag{1}$$

Based on the objective function - the total cost by (1) we determine the formula for calculating the optimum quantity of the delivery, which is called the Wilson or Andler formula:

$$Q_{opt} = \sqrt{\frac{2\lambda N_O}{N_S}} \quad [pcs, kg] \tag{2}$$

[1] *Marcela Pavlíčková, MSc., PhD.*, Technical University of Košice, Faculty of Mining, Ecology, Process Control and Geotechnology, Institute of Control and Informatization of Production Processes, Letná 9, 042 00 Košice, marcela.pavlickova@tuke.sk

[2] *Katarína Teplická, assoc. prof., PhD.*, Technical University of Košice, Faculty of Mining, Ecology, Process Control and Geotechnology, Institute of Business and Management, Letná 9, 042 00 Košice, katarina.teplicka@tuke.sk

Level of ordering inventory, which means the amount of inventory that if available in stock and falls below this level, it is necessary to make a new inventory order, is determined based on relation:

$$r = \mu - mQ^* \quad [pcs, kg] \tag{3}$$

where μ consumption of inventories during the delivery period ($\lambda\tau$), which is simultaneously equal to the amount of inventory in transit, m is the number of supply (a positive integer) on the road before the time of ordering ($\tau\ td$), Q^* is optimal level of stocks.

Based on these output parameters we determine the optimal amount of stocks at the store, the amount in which you need to make a new inventory order and the total cost of the process of supply and stockholding in the pellets store.

For the problem of the wood chip warehouse construction near the biomass boiler rooms we will use the model of recovery theory, so-called Bayess optimum principle. This model allows to determine the optimal location of the warehouse by a distance between the boiler rooms and based on the principles of probability theory.

We will use optimization model:

$$O = \sum_{i=1}^{n} a_{ij} p_j = max \tag{4}$$

where: a_{ij} is matrix of payments, p_j is probability of the economic phenomena.

The problem of turbogenerator recovery we will solve using the model of production equipment reproduction. This model arises in cases where we monitor the ways of utilization of production equipment in the production process of the company as a complex process, comprising a method of operation, maintenance and replacement of production equipment, that is the cycle of reproduction of production equipment from the moment of putting the production equipment into operation until its removal from use. The way of reproduction is determined by purchase of new production equipment or production equipment repair. The modes set purchase of new production equipment or production equipment repair. The optimal strategy for recovery of the manufacturing equipment will be the strategy where the average operating cost per time unit of utilization of the production equipment will be minimal.

Input parameters of the model are defined by probabilities. f_{x_t} is the probability of failure of a new equipment in the time interval $x_t =< 0, \ldots\ldots, T >$, g_{x_t} represents the probability of failure repair possibility, performing repairs in the time interval $x_t =< 0, \ldots.., T >$, h_{x_t} is the probability of failure of the repaired equipment that has been repaired at certain time x_t.

All input parameters i.e. probability of disturbances we obtain by statistical observation under practical conditions of production companies. O_C - cost of production equipment, expressed in value terms €, N_O – costs associated with repairing of production equipment attributable to one cycle of operation, ω_1 the average lifetime of a new production equipment in hours, changes, days, ω_2 average lifetime of repaired production equipment in hours, changes, days. Objective function when selecting an alternative solution method for reproduction of production equipment will have a cost character.

Determination of costs for the first condition: replacement of equipment for new N_{C_n}.

$$N_{C_n} = \frac{Q_C}{\overline{\omega_1}} \tag{5}$$

The cost of purchasing new equipment calculated over the average lifetime of new equipment:

$$\overline{\omega_1} = \sum_{t=1}^{n} t^s f(x_t) \tag{6}$$

Determination of costs for the second condition: repair equipment after a failure, and its use as a "new" N_{C_O}:

$$N_{C_o} = \frac{Q_C + (N_O p_t)}{\overline{\omega_1} + (\overline{\omega_2} p_t)} \tag{7}$$

Calculation of costs for repairing the equipment, after the general repair:

$$\overline{\omega_2} = \sum_{t=1}^{n} t^s h(x_t) \tag{8}$$

Calculation of the average lifetime of the repaired equipment:

$$p_t = \sum_{t=1}^{n} f(x_t)g(x_t) \tag{9}$$

Optimization consists of comparing the average cost per time unit of operation production equipment when deciding which of the recovery is more favorable for particular company conditions. Based on these models, we will address the optimization of various business processes.

Processes analysis and optimization

Inventory optimization project-pellets in the store will be assessed on the basis of Wilson's model of inventory optimization, based on actual data observed in the pellets store in the previous period. In the store are sold every year 13500 *tons* of pellets for heating houses. Supply of stocks is carried out at regular intervals of 1500 $tons/batch$. The purchase price for 1 *ton* is 185 €. The cost of importing a delivery to stores is 500 €. The cost of storing were estimated at 5 $€/year/tonne$. Shipping time from warehouse to the retail is around 5 *days*.

Based on Wilson's formula, we can determine the optimal amount of supply, which is based on the calculation of 1643.16 *tons*. If we evaluate it, then it is optimal for the store to ensure the delivery of this amount. Compared to the tracking the status of 1500 *tons* it would be appropriate to increase the amount per batch, which would save the store a shipping costs of new supply.

$$Q_{opt} = \sqrt{\frac{2*13500*500}{5}} = 1643.16\, tons \tag{10}$$

Important information for pellets store is also the amount of inventory that is in stock at the time of the new delivery. A calculation shows that by 183.6 *tons* it's need to make a new inventory order due to the delivery time of 5 *days*, during which the stocks might run out and unmet needs of the customer.

$$r = 13500*0.0136 - 0.164316 = 183.6\, tons \tag{11}$$

Optimum delivery would be the total cost including the first cost of pellets inventories of 2505716 €, in case that the amount of supply costs have decreased, the cost for its provision would steadily increase with increasing number of inventory turns.

$$N_C = \frac{13500}{1643.16} * 500 + \frac{1643.16}{2} * 5 + 13500 * 185 = 2505716\,€ \tag{12}$$

For the pellets store it is therefore advantageous to supply stocks in equal volumes of 1644 $tons/batch$, in that shipment would be the cost of acquiring, storing and maintaining a minimum.

For the problem of the wood chip warehouse construction near the biomass boiler rooms we will use the model of recovery theory, so-called Bayess optimum principle. In the area of residential buildings is heating provided by biomass boiler rooms and it is required to build between the boiler rooms a central wood chips warehouse, which would ensure smooth flow of material - wood chips to the boiler rooms. Boiler spatial distribution is as follows Fig. 1.

Distances between boiler rooms represent the kilometric distance for transport of wood chips to each boiler rooms and also in economic terms, the cost of transportation, which are a necessary cost to ensure smooth supply of wood chips to the boiler rooms. Consumption in individual boiler rooms are characterized by the probabilities that were specified by measurement and statistical evaluation of supply wood chips to each boiler rooms.

Tab. 1. Probability of use of individual bionass boiler rooms

Coefficient	A	B	C	D	E	F
P_j	0.11	0.24	0.31	0.02	0.26	0.06

Based on equation (4) we determine the matrix of payments for different combinations of distance between boiler rooms, and we have to comply with the constraint of the shortest path for the wood chips supply. Matrix of payments a_{ij} will be as follows Tab. 2.

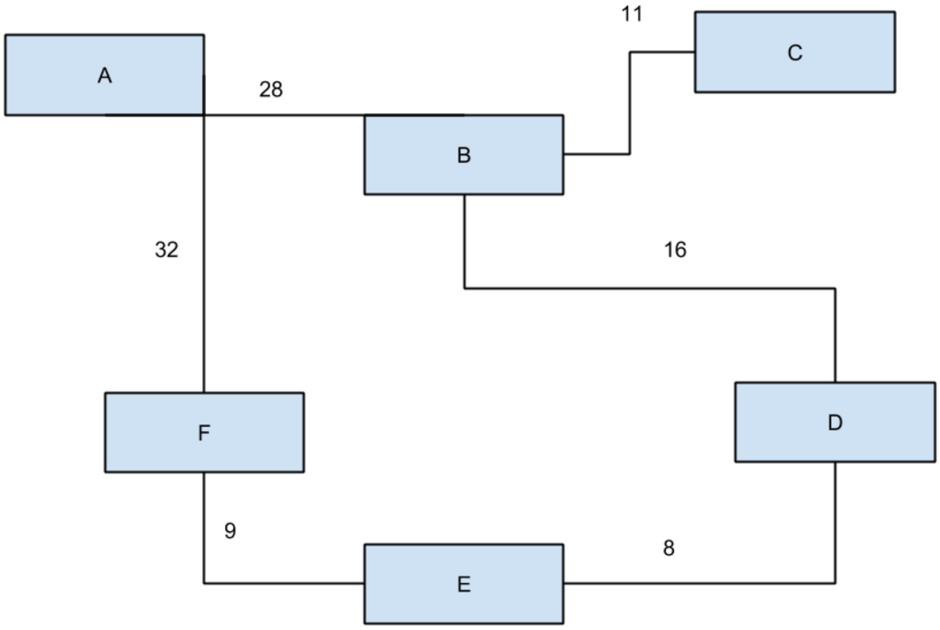

Fig. 1. Spatial distribution of biomass boiler rooms

Tab. 2. Matrix of kilometric distances between the boiler rooms

	A	B	C	D	E	F
P_j	**0.11**	**0.24**	**0.31**	**0.02**	**0.26**	**0.06**
A	0	-28	-39	-44	-41	-32
B	-28	0	-11	-16	-24	-35
C	-39	-11	0	-27	-35	-44
D	-44	-16	-27	0	-8	-17
E	-41	-24	-35	-8	0	-9
F	-32	-60	-44	-17	-9	0

This payments matrix represents kilometric distances between boiler rooms that transport vehicle must pass in order to secure the supply of wood chips in sufficient advance. Due to this fact it's needed to build a central wood chips warehouse, which would supply all the boiler rooms and in case of failure of normal supplies, wooden chips would be drawn from the central warehouse.

To calculate the optimal placement options of central warehouse we use Bayess optimum principle expressed by relationship (4).

Based on optimization we found that the best alternative for the location of wood chips warehouse construction will be at the *point B*, where it would be most effective, with respect to the distance of each boiler rooms and probabilities of supply of wood chips, to build a central warehouse.

The problem of turbo-generator recovery we will be solving using the model of production equipment recovery. Turbo-generator is a device which is subject to physical attrition and therefore requires a recovery plan due to its initial cost, which was 55500 €. Planned value after the first general repair would be 38200 €. Based on investigated properties of turbo generator, while watching the probability of its failure, the probability of failure after repair and the probability of equipment repair, we should decide what is more advantageous for the company management to make in terms of its repair or purchase a new turbo generator.

Calculation will be based on the relations (5)(6)(7)(8)(9) and the probabilities in Tab. 4. Based on the calculation, we found that the cost of new equipment, the purchase of a new turbo generator would represent with respect to its

Tab. 3. Optimization model for central warehouse location

	A	B	C	D	E	F	**total**
A	0	-6.72	-12.09	-0.88	-10.66	-1.92	-32.27
B	-3.08	0	-3.41	-0.32	-6.24	-2.1	**-15.15**
C	-4.29	-2.64	0	-0.54	-9.1	-2.64	-19.21
D	-4.84	-3.84	-8.37	0	-2.08	-1.02	-20.15
E	-4.51	-5.76	-10.85	-0.16	0	-0.54	-21.82
F	-3.52	-14.4	-13.64	-0.34	-2.34	0	-34.24

Tab. 4. Probability characteristics of turbo generator usage

Equipment age	1	2	3	4	5	6	7	8	9	10
f_{xi}	0	0	0.05	0.16	0.99	0.23	0.18	0.13	0.01	0
g_{xi}	1.1	1	0.96	0.81	0.8	0.65	0.63	0.64	0.53	0.44
h_{xi}	0.06	0.05	0.14	0.23	0.24	0.02	0.05	0.01	0.01	0

average lifetime 5349 €.

$$N_{C_n} = \frac{55500}{10.38} = 5349 \text{ €} \tag{13}$$

When calculating the cost of repairing the equipment, it is necessary to take into account the average lifetime of new and repaired equipment and also the price of new and repaired equipment. The cost of repairing the equipment would represent 6914 €.

$$N_{C_O} = \frac{55500 + (38200 * 1.32)}{10.38 + (3.746 * 1.32)} = 6914 \text{ €} \tag{14}$$

Based on the use of reproduction method model, we would suggest managers when deciding whether to buy or repair of the equipment to consider the option to purchase new equipment if the cost of its acquisition and use were lower than for its repair.

Conclusion

Quantitative methods represent the tools that managers can use for decision and support decision-making based on facts available. Optimization result is not always applicable in practice as the optimal strategy for the company, because the decision-making process is influenced by many other factors, such as manager characteristics, experience of professionals, financial coverage options of a chosen alternative, and conditions governing the practice, legislation and valid standards and other. Because the decision remains to managers, it is advisable to check the various alternatives also by means of mathematical modeling resp. simulation. Modeling in practice, however, requires systematically examine the whole problem to be solved, define the objectives and scope of solving the problem, analyze alternative solutions, verify the model and its benefits in practice, implement the model in practice and proceed to change the organizational structure of the company, change management and so on.

In addressing the economic problems of everyday practice is important to realize the importance of risk and its modeling in the company. Size of the risk depends on the conditions in which we solve a particular problem. Use of modeling and mathematical methods in solving economic problems in practice today is necessary because firms are burdened with high costs and the need to optimize - minimize by optimizing business processes.

Acknowledgement:
This work was supported partly by the Slovak Grant Agency for Science under grants VEGA: 1/0552/14, 1/0529/15 and by the Slovak Research and Development Agency under the contract No. APVV-0482-11.

References

Čuchranová, K., Vodzinský, V., 2003. Metódy ekonomickej analýzy, učebné texty. Košice, Edičné stredisko AMS. ISBN 80-8073-005-9.

Gros, I., 2003. Kvantitatívne metódy v manažérskom rozhodovaní. Praha, Grada Publishing. ISBN 80-247-0421-8.

Ivančová, Z., Brezina, I., 1997. Kvantitatívne metódy pre manažérov. Bratislava, Ekonómia. ISBN 80-88715-32-6.

Ivančová, Z., Brezina, I., Pekár, J., 2007. Operačný výskum. Bratislava, IURA Edition. ISBN 978-80-8078-176-7.

Kassay, S., 2001. Podnik svetovej triedy. Nové Zámky, Strateg. ISBN 80-88988-06-3.

Molnár, V., Fedorko, G., Stehlíková, B., Michalik, P., Kopas, M., 2014. Mathematical models for indirect measurement of contact forces in hexagonal idler housing of pipe conveyor. volume 47. Measurement. ISSN 0263-2241.

Potkány, M., 2005. Outsourcing, možná cesta k znižovaniu nákladov vo firme. In: Výkonnosť organizácie prístupy k jej meraniu a hodnoteniu. Slovenský komitét pre vedecké riadenie ZSVTS Bratislava, PDF PRINT s.r.o. Poprad. ISBN 80-968080-5-2.

Sidorová, M., Čulková, K., 2012. The use of cogeneration technologies for exploitation and refining of crude oil in Slovakia. In: Respect 2012. Košice. ISBN 978-80-553-0928-6.

Škrivánek, J., 2005. Kvantitatívne metódy finančných operácií. Bratislava,Iura Edition. ISBN 80-8078-074-9.

Teplická, K., 2012. Uplatnenie nástrojov operačnej analýzy v banskom podniku. Košice: ES TU FBERG. ISBN 978-80-553-0915-6.