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POSSIBILITY OF APPLICATION OF OPTIMIZATION METHODS TO SOLVE PROBLEMS IN MINING

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ABSTRACT

This paper presents a brief analysis of multi-criteria optimization, as a possibility for application in mining, in solving a problem. Multi-criteria decision can be applied in an optimum choice of mining method unearthed, the optimal choice of transport means, etc. In applying multi - criteria decision, most of the criteria according which will be select the most optimal alternative, can be taken into account.

1. INTRODUCTION

There are many optimization methods and other quantitative mathematical methods of operating researches that can be applied in the processes of decision making in designing and planning in mining. From this complex of methods, from the position of application, would put aside the following groups of methods for modeling:

- Single - criterion optimization models (for example linear programming, non - linear programming, dynamic programming, etc.);
- Multi - criteria optimization models (for example: methods ELECTRA, PROMETHEE, AHP etc..);
- Mathematical model optimization approaches developed to solve special cases when designing and planning in mining.

Mathematical model optimization approaches developed for specific cases in the planning and design in mining, basically are relatively good solutions because they are defined for modeling of real identified problem. This methodology is very effective but very complex. Complexity consists of a large amount of preparatory work for the definition and development of mathematical model that can be applied to solve some sort of problem with relatively good adaptability for use in similar cases.

2. GENERAL FOR MULTI - CRITERIA OPTIMIZATION

The increased number of criteria in multi - criteria optimization models mean not only the implementation of modeling, but also the increasing reliability of the results obtained. Optimization process is in a direct connection with the decision maker.

The large number of criteria has some advantages, but certainly has its shortcomings. Deficiencies are caused by the large number of criteria, by way

of their definition, the definition of their influences, or weights in the model, which in turn makes this process of mathematical modeling very complex. Even in modern conditions of development of mathematics as a science, there is no method which would be characterized by opshtost and power in solving the model.

Multi - criteria optimization models could be classified into two groups:

- Methods of multi - attribute decision or multi - criteria analysis
- Methods of multi - purpose decision.

Although multi - criteria optimization methods are complex, they have some common characteristics such as:

- A number of criteria (create by decision maker);
- Existence of conflikt between criteria;
- Each criterion has its own unit of measure and weight (cases when this condition is not fulfilled is rare);
- Subjectivity in optimization (impact of the decision maker);

The decisions of these kinds of problems are:

- Designing the best actions (alternatives);
- Selection of the best action from the set of predefined final actions.

2.1. Methods of multi - attribute decision

The basic element in the methods of multi - attribute decision making is attribute. Each attribute should provide a means of evaluation or assessment of the level of a criterion or goal. As a rule most of the attributes should be characterized by any specific action. They are based on the criteria selected by the decision maker. As synonyms for attributes are used: factors, parameters, features, components, performance and others.

Basic way of showing the problems with multi - attribute decision is form of matrices. Accordingly, the decision matrice O_{mxn} whose elements x_{ij} mark the values of t - th action a_j, in relation to the j - th attribute A_j (i = 1, 2, 3, ..., m, j = 1, 2, 3, ..., n).

$$O = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}$$

Actions in the problems of the multi - attribute optimization are described with two types of attributes:

- Quantitative;
- Qualitative.

Problems that arise are incurred by the complexity of comparation these two types of attributes, and treatment of various units of measure. Basically there are three kinds of scales that can be used for measuring different quantities (Hwang and Yoon, 1981):

- Ordinary scale;
- Scale of intervals;
- Scale of relations.

Ordinary scale ranked stock measured without taking account of the relative distances between ranks.

Scale of intervals ranks stocks with mutual equal intervals and define the differences between them and a predefined benchmark.

Unlike the scale of intervals, the scale of relations defines the differences between stocks and a benchmark that is not defined in advance.

Most methods use ordinary and scale of intervals in multi - attribute decision. Need of multi - attribute decision conditioned fast and continuous development of methods in this field. Therefore, today has a huge number of methods that are able to solve various complicated problems of multi - attribute optimization.

2.2. Methods of multi - purpose decision

Besides multi - attribute decision, multi - purpose decision is the second major group of methods for multi - criteria optimization.

Basically all methods of multi - purpose decisions have the following common characteristics:

- A set of goals that can be quantified;
- A set of well-defined active constraints;
- A set of continuous (infinite) activities;
- Process for obtaining information (explicit or implicit) about identified targets (not quantified).

General mathematical formulation of a problem with multi - prpose decision, often represented in the following form:

$$\max \{f_1(x), f_2(x), \ldots, f_n(x), p \geq 2\}$$
$$g_i(x) < 0, \; I = 1, 2, \ldots, m$$
$$x \geq 0$$

where:
n – number of variables, j = 1, 2, …, p;
p – number of functions of criteria, k = 1, 2, …, p;
m – number of constraints;
x – n-dimensional vector of variables x_j, j = 1, 2, …, n;
$f_k(x)$ – function of criterion, k = 1, 2, …, p;
$g_i(x)$ – constratints, i = 1, 2, …, m.

In general, the term multi - purpose decision means maximization of the function of the criterion with given constraints. Because the criteria of minimization can be translated into criteria of maximization, such as s-th criterion applies:

$$\min f_s(x) = - \max \{-f_s(x)\}, \quad s \in \{1,2,\ldots,p\}$$

When all the functions and constraints are linear (eg, with the symbol "≤"), the model of multi - purpose decision has the following form:

$$\max \{f_k(x) = \Sigma_j c_{kj} x_j,\ k = 1, 2, \ldots, p;\ p \geq 2\}$$
$$\Sigma_j a_{ij} x_j \leq b_i,\ i = 1, 2, \ldots, m$$
$$x_j \geq 0,\ j = 1, 2, \ldots, n$$

where:
c_{kj} – coefficient of k-th function for j-th variable, k = 1, 2, …, p; j = 1, 2, …, n;
a_{ij} – parameter in the i-th constraint of j-th variable, i = 1, 2, …, m; j = 1, 2, …, n;
b_i – free member i-th constraint, i = 1, 2, …, m.

3. MOST OFTEN APPLIED METHODS FOR MULTI - CRITERIA OPTIMIZATION

Most famous of multi - criteria optimization methods are the methods ELECTRA, the methods PROMETHEE and method AHP, which fall into the methods of multi - attribute decision.

3.1. Method ELECTRA

ELECTRA method under the term means a set of methods for solving problems of multi - criteria optimization. The name ELECTRA is derived from the English expression: Elimination and et choise translating reality which means: the elimination and real transmission choice. This method was presented for the first time by Roy in 1971. There are several variants of this method. Most famous are variants ELECTRA I, ELECTRA II, ELECTRA III and ELECTRA IV. Last, and recently developed varieties are ELECTRA IS

and ELECTRA TRI. Most applied variant (method) is the basic ELECTRA I, with which partly ranking of alternatives is done. ELECTRA II method is used in cases of full rank set of alternatives.

This group of methods allows the ranking of the set of solutions for discrete problems and heterogeneous criteria functions. The models include subjective assessments, with the values of the criteria functions and through the relative importance of individual criteria. ELECTRA III, ELECTRA IV and others are called methods of "high" range.

3.2. Method PROMETHEE

PROMETHEE method is one of the newer methods in multi - criteria analysis, which was developed in the following variants: PROMETHEE I, PROMETHEE II, PROMETHEE III, PROMETHEE IV, PROMETHEE V, and as newer versions PROMETHEE VI, PROMETHEE GDSS and PROMETHEE GAIA. It is named from expression: "Preference Ranking Organization Method for Enrichment Evaluations". Basics of the methods PROMETHEE were made by J. P. Brans (1984), J. P. Brans and B. Marschal (1984), J. P. Brans and P. Vincke (1985) and B. Marschal (1985).

The main feature of this method is the use of six so-called generalized criteria for defining the decision maker preferences, for the specific criteria of a problem. Decision maker itself may introduce new types of generalized criteria and to express their preferences in terms of relevant criteria.

As in other multi - criteria methods, in methods of PROMETHEE is possible to define the weights of the criteria.

PROMETHEE I provides an opportunity for partial order of alternatives. Unlike the method PROMETHEE I, PROMETHEE II method offers complete order. With the method PROMETHEE III provides ranking in the intervals and finally with the method PROMETHEE IV is done multi - criteria optimization of continuous range of alternatives. Method PROMETHEE V, PROMETHEE VI and others are relatively new and insufficiently tested methods.

The basic advantages of the PROMETHEE method compared to other methods, but primarily in terms of method ELECTRA are:

- Greater ease;
- Introduction of generalized criteria functions reduce subjectivity in decision-making;
- Parameters that are used have their economic explanation and meaning;
- Effects of the ranking is completely eliminated.

The main feature of the method PROMETHEE II - complete ranking of alternatives classifies this method as one of the methods which are the most acceptable for solving problems with multi - criteria optimization. Should have in mind that the method PROMETHEE II in relation to the PROMETHEE I

method differs only in certain procedures that after partially ranking would set the total order of alternatives.

3.3. Method of Analytic Hierarchy processes (AHP)

Method of analytic hierarchical process is developed by Tomas Saaty (1980). AHP method is one of the classical methods for multi - criteria optimization, which allows solving very complex problems with many areas, a large number of criteria and multilateral periods.

The areas of application of the AHP method is multi - criteria optimizing and deciding on a defined set of criteria and alternatives, and the choice of the best alternative is made, i.e. shows complete order for the meanings of the alternatives in the model.

4. CONCLUSION

When you take a decision when designing or planning in mining, it is necessary to take account of it to achieve greater business performance, to provide safe working conditions, which have lower operating costs or to achieve greater financial gains. To be fulfilled all these requirements, it is necessary to take into account the large number of influential factors, or criteria. Separate criteria have equal impact on a separate alternative, so normalized weights for each criterion are given.

Multi - criteria optimization allows the inclusion of more criteria, or relevant factors, which achieves greater accuracy in selecting or in the decision. From multi - criteria optimization methods the most applied are as follows:

- Method ELECTRA;
- Method PROMETHEE;
- Method AHP etc.

In making a final decision when designing or planning in mining, it is desirable to solve the problem using three multi - criteria optimization methods, then be performed to compare the results obtained by the three methods, and a final decision, i.e. to choose the best alternative.

The application of information technology today much simplifies the resolution of certain issues or task. Major opportunities of the computing machinery storage many data and performing many calculations, enabling them to find and use when solving problems in mining.

In this regard, there are already developed computer programs for the multi - criteria optimization methods: ELECTRA I, PROMETHEE II and AHP.

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