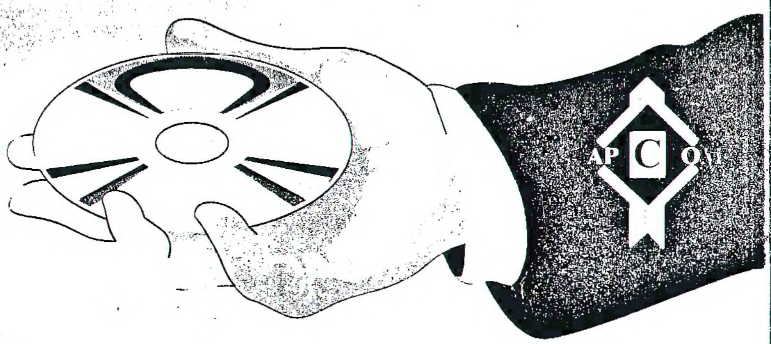
2nd Regional
APCOM'97 SYMPOSIUM
on

COMPUTER APPLICATIONS AND OPERATIONS RESEARCH IN THE MINERAL INDUSTRIES



MOSCOW, RUSSIA
August 24-28, 1997

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2nd
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APCOM'97
Symposium

on

COMPUTER APPLICATIONS AND OPERATIONS RESEARCH IN THE MINERAL INDUSTRIES

L.A. PUCHKOV
Editor

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FOREWORD

This volume contains the Proceeding of the 2nd Regional Symposium on the Application of Computers and Operations Research in the Mineral Industries (APCOM), held at the Moscow State Mining University, Russia, on August 24–28, 1997.

The Symposium series on the Application of Computers and Operations Research in the Mineral Industries was initiated by the University of Arizona in 1961. Since the first regular APCOM Symposium has been organized, a long series of successful APCOM Symposiums were held in different countries, where representatives of the leading research and educational institutes, universities and mining enterprises are coming from.

The first Regional APCOM Symposium was held in Bled, Slovenia, in 1994. The Moscow Symposium continues the new series given the name Regional APCOM Symposium. They do not differ from regular ones except that they are focused to a certain region and majority of papers are expected to come from respective surrounding area.

APCOM Symposiums have a common objective which they share with scientists and engineers in the field; to contribute to the effectiveness of the decisions made by managers in the mineral industries. The Symposiums deal with the application of quantitative techniques to problems in the mineral industry; the use of computers in this process is sometimes significant, sometimes incidental. The APCOM Symposiums have been closely identified with educational institutions and professional societies in the different countries.

Such interaction and cooperation between industries, academia, and professional societies is vital to the success of APCOM.

APCOM has always maintained the perspective directions in the field of operations research and computer applications in mining industries. It is important to recognize that age–old problems must be re–solved under different and changing conditions. The Proceeding of the 2nd Regional Symposium reveal no exception to this trend.

The Proceeding contains 110 papers. They show a professional review of state–of–the–art of this specific field of Mineral Science and Industry. A great number of institutions and people was engaged in different activities of organization of this Symposium. We have to express our deepest thanks to the International APCOM Council for the support of the idea of regional conferences, organizing committees, reviewing persons, editors, chairpersons of different sessions, and, first of all, authors of papers and participants of the Symposium for its success.

To all institutions and individuals, our great appreciation.

August 24, 1997

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TABLE OF CONTENTS

1. Keynote Session

2 Open Pit Mine Operations and Scheduling - I

3 Mine Design, Planning, Operations Underground - I

4 Geostatistics - I

5 Open Pit Mine Operation and Scheduling -II

6 Mine Design, Planning, Operations Underground -II

7 Geostatistics - II

8 Open Pit Design and Modelling

9 Rock Mechanic Simulation -I

10 Mineral Processing Applications - I

11 Open Pit Planning

12 Rock Mechanic Simulation - II

13 Mineral Processing Applcations - II

14 Investment Planning and Project Evaluation

15 Ground Control and Rock Fragmentation

16 Mineral Processing Applications - III

17 Equipment Operations Modelling

18 Mine Ventilation Systems

19 Human Resource Development - I

20 Environmental Issues and Waste Management - I

21 Human Resource Development - II

22 Environmental Issues and Waste Management - II

RAISING THE TRUSTWORTHINESS OF PLANNING OF THE DEEP HORISONTS OPEN-CAST MINES

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Raising the stripping and extracting works prime cost with increase of the quarry working-out depth is bound up with worsening of the geological and mining-technical conditions, increase of the distance of mining mass transportation, use in most cases of the low-effective for the deep horizons complexes of the equipment and technological schemes. These appropriatenesses ignoring takes place under the traditional "manual" methods of projecting and planning of the open-cast mining works and leads to acceptance of the non-correct decisions, drop in the enterprises production indices.

The proposing methods allow to define the in-horizon component of the stripping and extracting works prime cost, to calculate the part of expenses, falling on the equipment concrete complex, working under given mining-technical conditions. With this, the possibility of prognostication in time and (under the mining works lowering) of the ore and strip prime cost meanings at the appointed terrace arises.

The technical- economic indices of the mining enterprise activities for the past periods are the initial information for the calculations, the work indices of the quarry, exploiting under analogous conditions, are the information by projecting. Practically extracted volumes of ore and strip by the past periods with breaking up by the concrete extracting, stripping complexes and the work horizons with the differentiation by the working out years, the average annual meanings of the prime cost of ore and strip at the quarry as a whole are used as the pointed data. The good results may be achieved by way of introduction of the correction factors, analogous to the discounting indice, allowing to lead the economic indices taking place at different times to the one period.

The essence of the proposing methods is that at the base of the available initial data the system of the T linear equations with N unknown quantities is worked out, where T is the number of the quarry exploitation periods (the years), taking into account by calculation, and N is the number of the calculated meanings of the ore or strip prime cost differentially by the working out years and equipment complexes.

The following parameters are the initial data of the problem :

- the quarry exploitation date at the moment of calculation - T years;
- the total quantity of the extracting (stripping) terraces, involving in work for the expiring period - N ;
- the total annual prime cost of the unit volume of ore (strip) - C_t ;
- the annual volumes of the extracting (stripping) works at the quarry as a whole-Q_t
- the annual in- horizon volumes of the extracting (stripping) works - G_{tn} .

The unknown parameter is the in- horizon component of the extracting (stripping) works prime cost - c_n.

As a whole the problem is described by the system of the T linear equations with N unknown quantities of the following type:

$$G_{11} * c_1 + G_{12} * c_2 + \ldots + G_{1N} * c_N = Q_1 * C_1$$
$$G_{21} * c_1 + G_{22} * c_2 + \ldots + G_{2N} * c_N = Q_2 * C_2$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$
$$G_{T1} * c_1 + G_{T2} * c_2 + \ldots + G_{TN} * c_N = Q_T * C_T \quad (1)$$

In general case the linear equations system (1) comes to the classic system of equations of the type Ax = b by $T \geq N$.

The problem realisation allows to analyse the efficiency of the mining equipment use at the extracting and stripping works at the various depths of the quarry's work. By definition of the in-horizon component of the stripping and extracting works prime cost with taking into account of the variety of using mining equipment the following initial parameters are given in addition :

- the quantity of types of the mining equipment, employing by the extracting (stripping) works - R ;
- in-horizon volumes of the extracting (stripping) works to every type of the mining equipment by the work years - V_{tnr}.

The unknown parameter is the in-horizon component of the extracting (stripping) works prime cost for the r-th type of the mining equipment (c_{nr}). As a whole the problem is described by the system of T linear equations with N * R unknown quantities of the type:

$$V_{111} * c_{11} + V_{112} * c_{12} + \ldots + V_{11R} * c_{1R} +$$
$$V_{121} * c_{21} + V_{122} * c_{22} + \ldots + V_{12R} * c_{2R} + \ldots +$$
$$V_{1N1} * c_{N1} + V_{1N2} * c_{N2} + \ldots + V_{1NR} * c_{NR} = Q_1 * C_1$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$
$$V_{T11} * c_{11} + V_{T12} * c_{12} + \ldots + V_{T1R} * c_{1R} +$$
$$V_{T21} * c_{21} + V_{T22} * c_{22} + \ldots + V_{T2R} * c_{2R} + \ldots +$$
$$V_{TN1} * c_{N1} + V_{TN2} * c_{N2} + \ldots + V_{TNR} * c_{NR} = Q_T * C_T \quad (2)$$

The solution of the linear equations systems (1), (2) can be found only at the case, when $T \geq N$. In practice, especially for the initial periods of planning, this condition is fulfilled not always because of shortage of the initial data. In order to provide the possibility of the solution receiving the artificial method of lowering of the problem dimension is offered. It is achieved in next way. The upper terraces, the quantity of which is L, L=N-T+1 are jointed conditionally and are considered later on as the indivisible horizon of work. Volumes of the extracting (stripping) work in these horizons are summed up and are considered also as for united terrace. In result of the problem solving the prime cost meaning is defined, which is considered also as the common one for all the L upper horizons. In analogous way one can deal by calculation of the in-horizon component of the extracting and stripping works prime cost with taking into account of the using mining equipment. By the great number of the initial data, which is typical by the prolonged periods of the quarry exploitation, the problem's dimension can be also lowered in way of unification of the several adjoining in time periods of the quarry work in common stage. With this the volume and cost indices for the uniting periods are summed up, and later on their results are considered as the unit indices. The above- described methods can be applied with the purpose of coming of the linear equations system to the classic type, i.e. when the number of unknown quantities is equal to the number of the equations (T=N or T=N*R depending on the class of the solving problem). There are a lot of approved methods, providing the receiving of the exact solutions, for the solving of the linear equations system of such type.

In process of the quarry exploitation the initial data are enriched continually, that is why the in-horizon components of the prime cost are recalculated periodically with the purpose of raising of their calculated meanings trustworthiness.

The methods of statistical prognostication are offered for prognostication of the indices. Abroad the statistical prognostication becomes the inalienable attribute of the economic activities of any independent economic unit- from the small firms to the large companies. With this at the base of discrete data of the past periods or stages the functional dependencies are built. The optimal one is chosen from all the dependencies by one criterion or by the whole complex of criterions. And this dependence is the base for the economic indices prognostication.

According to investigations of C.D.Liues (Liues C.D. The methods of the economic indices prognostication, 1986) the following functional dependencies are recommended for use: the linear one ($y=a*x+b$); the exponential one ($y=a* e^{bx}$); the powerone ($y=a*x^b$); the hyperbolic one of the 1st type ($y=a+b/x$); the hyperbolic one of the 2nd type ($y= 1/(a+b*x)$); the hyperbolic one of the 3d type ($y=x/(a+b*x)$); the logarithmic one ($y=a+b*\ln(x)$); the dependence of the S-form ($y=e^{(a+b/x)}$); the inverse - logarithmic one ($y=1/(a+b*\ln(x))$); the modified exponent ($y=a+b* c^x$); the Hompertz curve ($y=a* b^c$);the logistic one ($y=1/(a+b*c^x)$).At the adduced dependencies the work periods or work horizons may be taken as the argument x depending on the solving problem type. The function Y defines the unknown numerical meaning of the economic indice.

By choice of the best functional dependence it is offered to follow the next criterion estimates: the determination coefficient - δ; the average square of the error - β; the correlation coefficient - γ ;the average- absolute error, in percent - α .

Table1. The calendar volumes of ore extraction for the polymetal deposit.

Number of horizont	The volumes of ore extraction in the working-out years, ths t							
	1st	2nd	3rd	4th	5th	6th	7th	8th
H-1	87.13							
H-2	191.04	94.99	40.06	11.24				
H-3	154.23	480.2	237.8		6.38			
H-4		41.59	338.9	555.8	193.8	66.2		1.6
H-5				172.6	379.3	162.3	253.8	84.4
H-6					160.0	474.4	441.0	131.6
H-7							170.0	883.3
H-8								135.5
Total	432.4	616.8	616.8	739.6	739.4	703.0	864.7	1263.3
Prime cost of 1 ton	13.84	12.47	15.95	12.62	12.78	14.77	13.95	14.75

The practical approbation of the elaborated methods has been carried out at the example of the polymetal deposit. The initial data of the extracting works are adduced at the tab.1.

The prime cost of ore 1 ton in work years is given in the conditionally constant monetary units. The results of the definition of the extracting and stripping works prime cost component are adduced at the tab.2. The

Table 2. Data of the in-horisont component of the ore (strip) 1 ton prime cost.

Number of horizont	In-horizont component of	
	the ore prime cost	the strip prime cost
H-1	13.78	0.273
H-2	13.82	0.286
H-3	13.47	0.461
H-4	14.97	0.742
H-5	8.95	1.905
H-6	16.92	-
H-7	13.71	-
H-8	23.35	-

prognosticated results of the meanings of the ore 1 ton prime cost in-horizon component at the lower work horizons, subject to work out, are adduced at the tab.3. The results of prognostication for the four low- laying work terraces are adduced at the table . In connection with the criterion meaning for the quarry as a whole for the next periods - at the fig.2.

The definition of the prognosticating indices of the stripping and extracting works prime cost allows to plan the mining works at the quarry more groundly. And for perspective prognostication it is

Table 3. The prognosticating meanings of the in-horisont component of the ore 1 ton prime cost.

Functional dependence	Meanings of the criterion estimates				Meanings of the prime-cost in-horisont component			
	δ	β	γ	α	H-9	H-10	H-11	H-12
$Y = A+Bx$	0.25	10.73	0.50	18.5	18.61	19.45	20.28	21.12
$Y = A * e^{bx}$	0.17	10.77	0.41	17.7	17.65	18.46	19.32	20.21
$Y = A * x^{b}$	0.03	12.67	0.28	17.6	15.82	16.00	16.17	16.32
$Y = 1 / (A+Bx)$	0.13	11.72	0.36	17.6	16.49	17.18	17.93	18.75
$Y = A+B * \ln(x)$	0.13	12.46	0.37	18.5	16.70	16.92	17.12	17.30
$Y=1/(A+B*\ln(x))$	0.08	13.66	0.28	17.0	14.90	15.02	15.13	15.24

estimates for the different functional dependencies have the discrepant meanings, the results of prognostication, achieved by the 6 functional dependencies, are adduced at the tab.3. The diagram of change of the ore prime cost by lowering of the open-pit mining works is adduced at the fig.1, and the change of the ore prime cost recommended to use the prognosticated calendar meanings of the prime cost. So the criterion of optimum for choice of the work rational variant has the form :

$$\sum_{1}^{T} П_i=\sum_{1}^{T}(Ц_i * Q_i^{M}-(C_i^{p} * Q_i^{p}+C_i^{п} * Q_i^{п})) \rightarrow \max ,$$

where $П_i$ is the profit at the i-th year; $Ц_i$ is

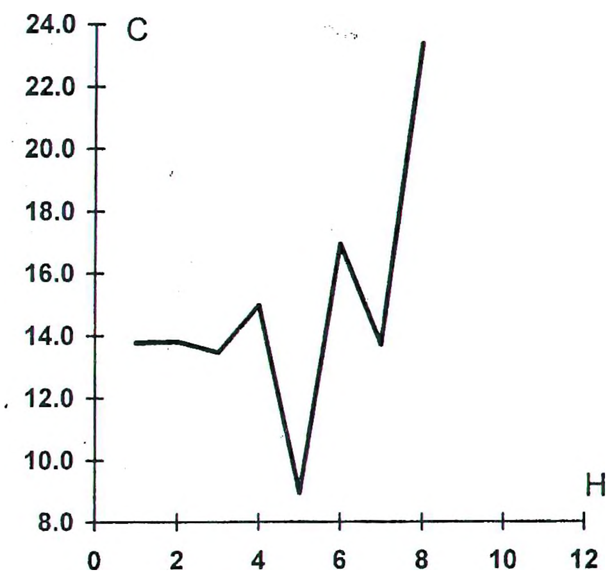

Figure 1. Prognostication of the ore 1 ton prime cost meaning by the planning of the quarry deep horisonts working-out (The conditional mark of horisont is situated by abscissa axis, and the prime cost-by ordinate axis).

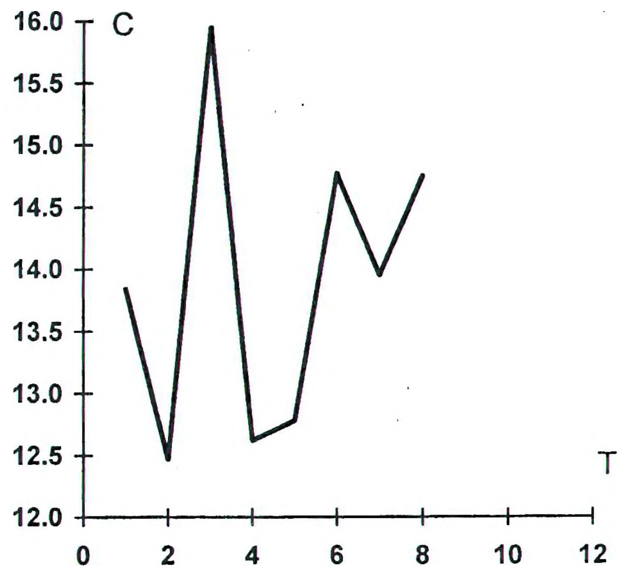

Figure 2. Prognostication of the ore 1 ton prime cost meaning for the entire quarry as a whole for the nearest periods (The working-out year is shown by abscissa axis, the prime cost-by ordinate axis).

the metal price in the i-th year; Q_i^m is the quantity of metal, extracted in the i-th year; C_i^p, C_i^n is the ore and strip 1 ton prime cost in the i-th year by the quarry ; Q_i^p, Q_i^n are the volumes of the extracting and stripping works in the i-th year by all quarry as a whole.

By foundation and choice of the rational variant of the working-ou from a lot of the possible calendar (annual or quarter) mining works plans it is offered to use the following criterion of the optimum :

$$\sum_{1}^{K}(C_k^p * Q_k^p + C_k^n * Q_k^n) \rightarrow \min ,$$

where C_k^p, C_k^n is the prime cost of ore and strip 1 ton at the k-th work horizon; Q_k^p, Q_k^n are the ore and strip volumes, extracting from the k-th horizon, K is the number of horizons, involving into working out at the planned period.

The given methods realisation allows with use of the computer technologies at the base of personal computers to analyse the current activities of the mining enterprise in way of definition of the differential (in-horizon) components of the ore and strip prime cost, to prognose the economic indices meanings for the nearest periods, to estimate economically the work of the concrete mining equipment at the appointed stripping or extracting terrace and prognose the efficiency of its use at the low-laying horizons, to raise the trustworthiness of planning of the quarry's deep horizons working-out.

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