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PLANNING FOR PLANNING--COAL: ISSUES FOR THE EIGHTIES

Proceedings of an IIASA
Task Force Meeting,
November 24-27, 1980

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November 1982
CP-82-80

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PREFACE

This Collaborative Paper contains the technical papers presented at IIASA's Task Force Meeting held at the Institute in November 1980 entitled "Planning for Planning--Coal: Issues for the Eighties".

This meeting was part of a research program at IIASA under the generic title 'Issues for the Eighties' in which systems analysts and managers from a given industry met to exchange ideas and information, as well as to explore and develop a strategy of using systems analysis, rather than using it merely as a tool to be brought in for certain well-defined problems.

The subject of the task force meeting was to explore the use of systems analysis in the planning of new capacity for deep minging in hard coal. In fact, the planning of any major project or enterprise, but especially a colliery is, in itself, an extremely complex process which, by definition, requires planning, i.e., planning must itself be planned. Hence the title of this seminar.

The discussion was attended by 17 representives from 7 countries, and 13 papers were presented or tabled at the meeting.

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REALISTIC ASSESSMENT OF RESERVES

Joachim Scholz
Dr. Henning Kublun

In long-wall mining too it is to be assumed that the worked panel is not recovered completely. The trend towards high working losses was intensified in recent years by cost constraints and the need to mechanize.

For a realistic assessment it is to be allowed for the existing geological reserves being only recovered to the half or even less of their actual volume. By allowing for losses of different volume the results of long-term planning and the resulting evaluation criteria were influenced to a large extent.

Ruhrkohle AG established standard principles for assessment of the probably recoverable part of the geologically determined reserves covered by planning.

In a first phase the standard mine survey records need to be updated. This updating is carried out according to standard requirements and covers fault structure of the main levels, the profiles of the panel axes, and the seam profiles. In the drawings of the fault-structure system the 'tectonic areas" are particularly marked. By means of these drawings all geologically available reserves are assessed by a standard Ruhrkohle method which implies a variety of "tectonic code figures". This way of assessment is based on "tectonic laws of hard coal reserves in the Ruhr area" established by Dr. Ehrhardt.

The realistic reserve assessment is based on the updated "Geologischer Vorrat (geologically determined reserves)" of the planning area of the colliery concerned which then is stepwise reduced to "Zuschnittsvorrat (reserves to be considered for future layout)", the "Planvorrat (reserves to be considered for production planning)", and eventually to the "Abbauvorrat (the reserves actually available for production)". These steps are explained in the following passages.

Out of the "Geologischer Vorrat" hereafter referred to as GV, seams or panels are selected according to estimate criteria applied specifically for the colliery in question. These seams or panels are to be considered in the development planning phase; they are the "Geologischer Planvorrat" hereafter called GPV.

When subdividing the GPV into panels to be worked the "Zuschinittsvorrat" hereafter referred to as ZV is obtained. ZV is determined by the geometric features of the panel, the probable seam thickness, the ash content of the seams, and the expected quality of the saleable output.

From ZV the "Planvorrat" hereafter referred to as PV is determined by calculated reductions in the volume of which is determined by the expected fault intensity (tectonic code figures), the intended worked seam thicknesses and the reliability of knowledge on geological conditions in the tectonic element at the time of layout conception of the panels. These calculated reductions are determined in the following way:

$$\boxed{\Delta\ \text{reserve}_{ZV-PV} = \left[\Delta\ \text{reserve}_{ZT}\ \text{x}\ \Delta\text{reserve}_{MKB}\right] \times \begin{array}{c}\text{reduction}\\ \text{factor}\end{array}}$$

The following should be noted with respect to the individual elements of this formula: In case of the tectonically conditioned calculated reductions Δ reserve_{ZT}, difference needs to be made according to the working losses of the seam worked first in a specific tectonic area and the losses in the subsequently worked seams in the area which then is partially known. The first seam is mostly of more than 1.5 m of thickness worked; due to non-ascertained knolwedge of the deposit, tectonic faults is worked through more often by the face. In the subsequently worked seams greater calculated reductions are made for the idealized layout of the panel since the meanwhile known in-situ tectonics which affect coal winning are lateron, in the actual layout, increasingly kept away from the panels actually worked.

Comparisons of the layout of virgin takes in the initial planning phase with the actual working layout, resulted in an assumption for the deposits of the Ruhr covering the graphically shown interdependence between the fore-case tectonics (ZT) and the resulting calculated reductions (Δ reserve$_{ZT}$):

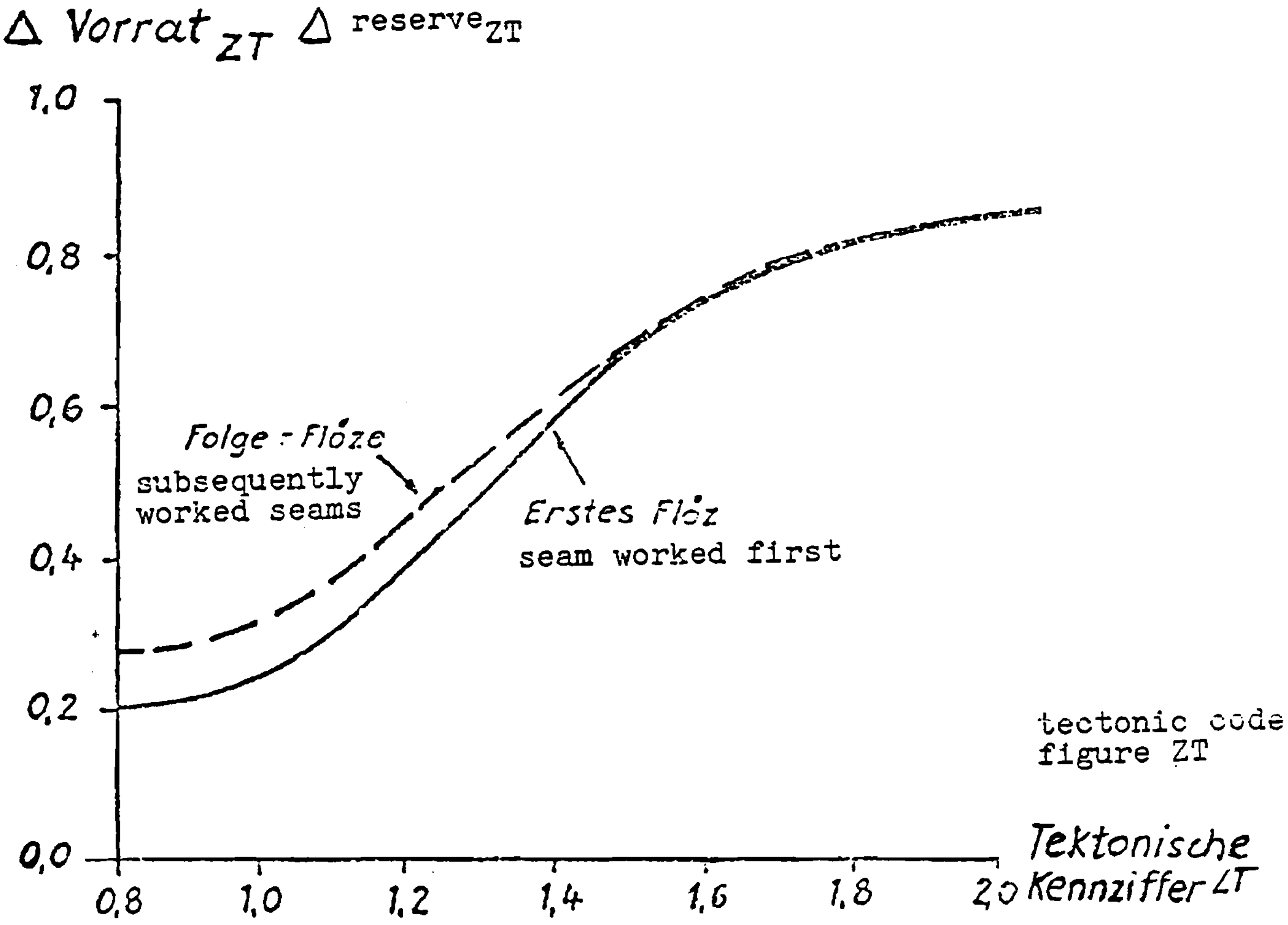


Figure 1. Tectonically conditions calculated reduction versus the tectonic code figure.

For tectonic code figure values > 1,4 no significant difference is noted between the first seam and the subsequently worked seams.

For EDP purposes the required functions are formulated as follows:

Calculated reduction for the first seam:

$$\boxed{\Delta \text{ reserve}_{ZT} = 0{,}9 - \frac{0{,}1}{0{,}147 + ZT - 0{,}8^{3}}}$$

Calculated reduction for the subsequently worked seams:

$$\boxed{\Delta\ \text{reserve}_{ZT} = 0{,}875 - \frac{0{,}082}{0{,}141 + ZT - 0{,}8}^{3}}$$

When determining the influence of the seam thickness on the volume of the calculated reductions, expressed by the formulated value reserve$_{MKB}$ it should be considered that, by experience, tectonic faults of identical order of magnitude imply higher working losses with decreasing seam thickness. This applies in particular for seams of less than 1.5m of worked thickness, as shown below.

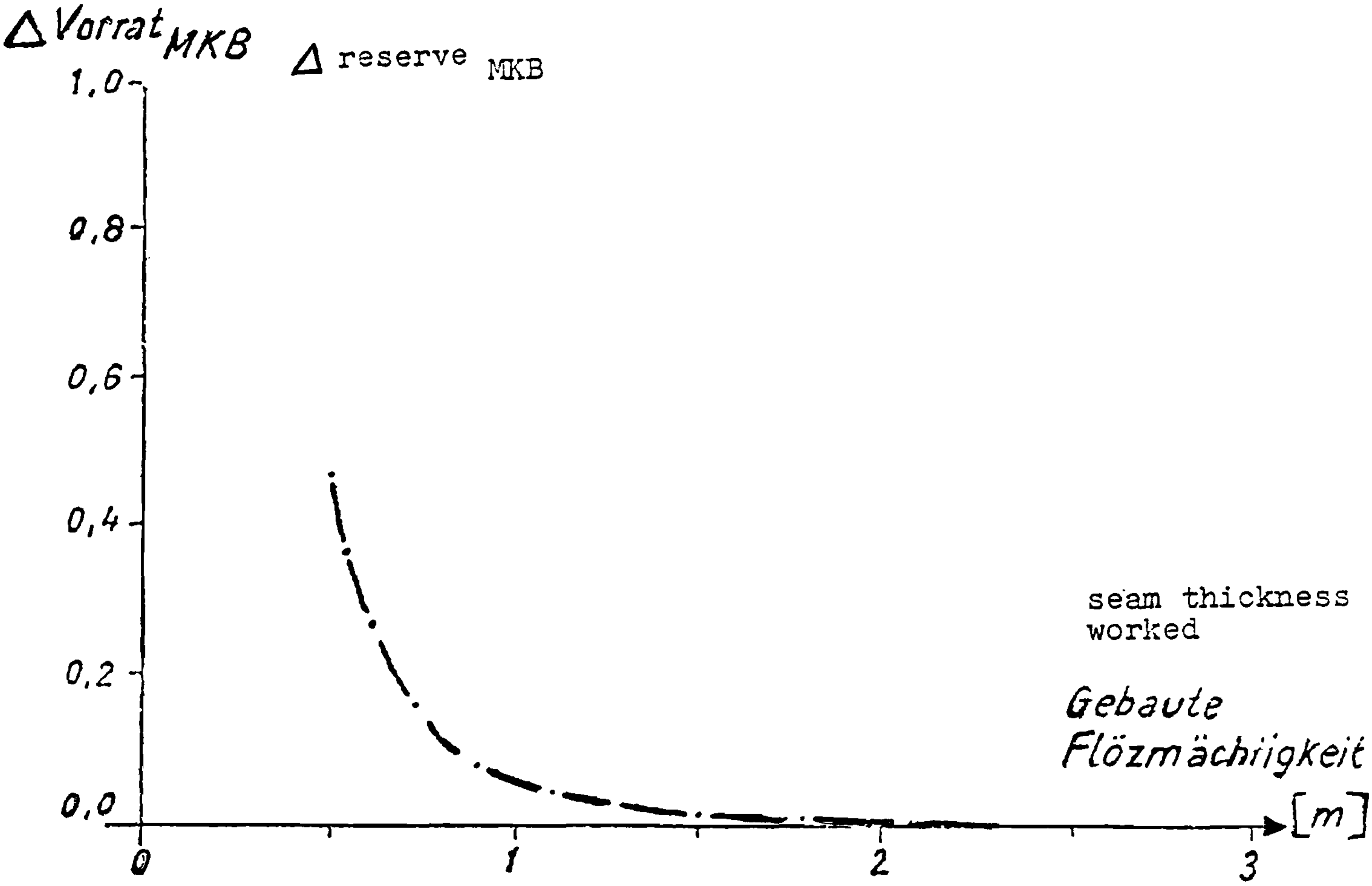


Figure 2. Calculated reduction versus the seam thickness worked

The mathematical formula reads:

$$\boxed{\Delta\ \text{reserve}_{MKB} = \frac{0{,}06}{MKB^{3}}}$$

For the volume of the calculated reductions it is of importance whether assured knowledge of the tectonic area provided for production is available. In those tectonic areas were detailed knowledge of the seam at the time of layout planning was not available the working losses with respect to the initial layout are, by experience, comparably high, and the layout necessarily needs to be more two-dimensional than in known areas.

In areas which are better known either through working of neighbouring seams or through rise headings or road-headings, the layout planning normally is also less two-dimensional, i.e., the working losses--as a percentage of the ZV will remain less than in non-explored "white" areas. The necessary calculated reductions of reserves become smaller with increasing knowledge of the take. This fact is allowed for by the reduction factor as a function of the degree of knowledge (Figure 3).

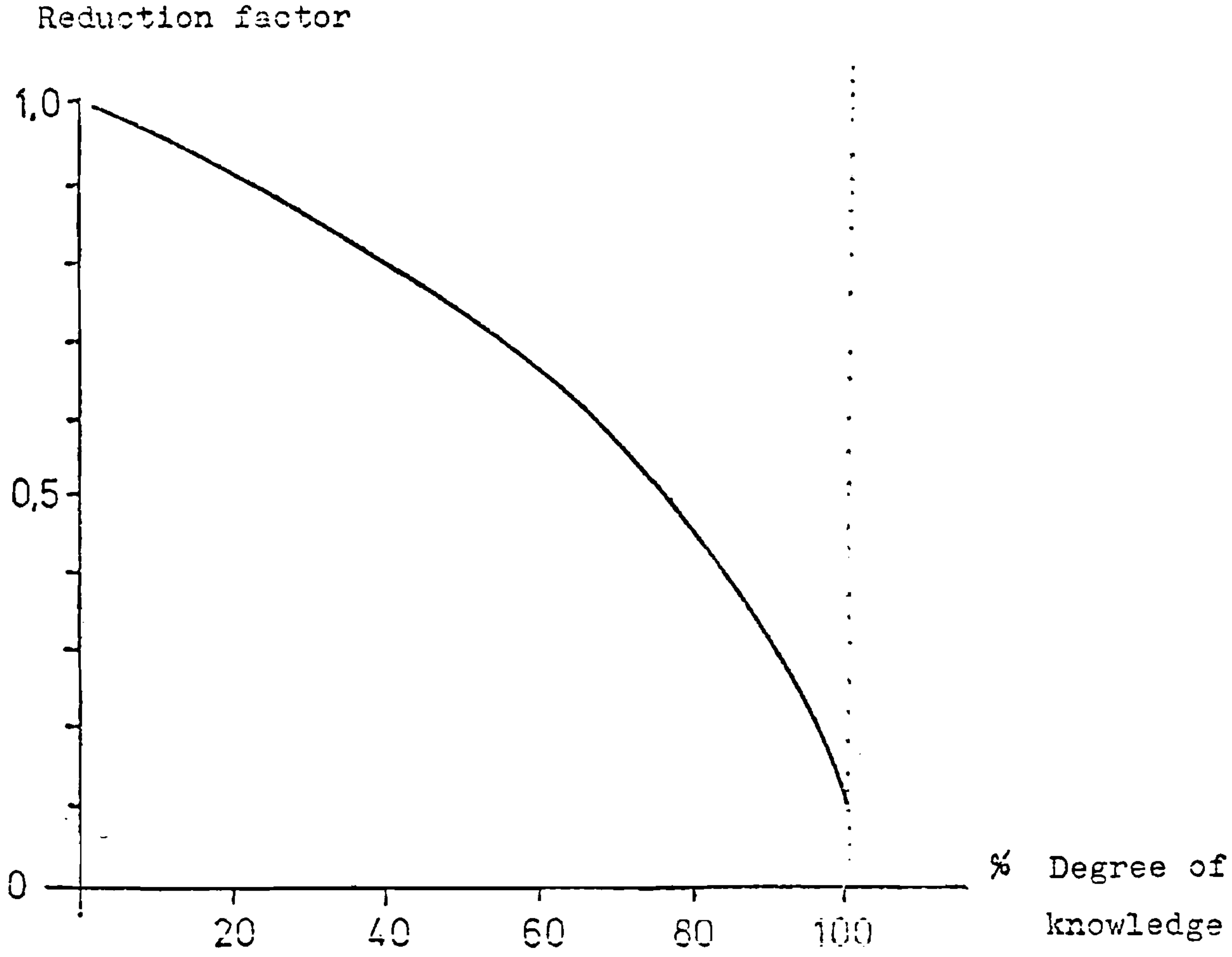


Figure 3. Reduction factor reduced with increasing degree of knowledge

The formula reads:

Reduction factor = 0,1 x   101 - degree of knowledge

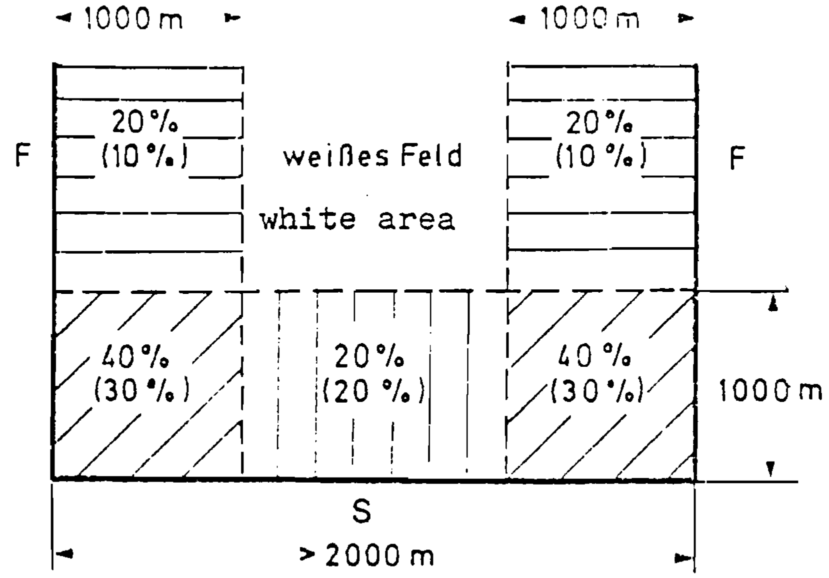
The degree of knowledge of a panel subject to layout is expressed in per cent and determined by the quality of the knowledge gained directly in the seam to be worked and in the neighbouring seams. Overlapping work in neighbouring seams yields well-established knowledge while linear exploration is less reliable. The fact that even at a 100% degree of knowledge the reduction factor is > 0 means that even with best exploration, losses is to be allowed for with respect to ZV.

The determination of the degree of knowledge to be incorporated into the formula for takes subject to layout is based on a catalogue established by empirical evaluation of detailed investigations. Complete overlapping by workings in less than 200 m of distance means a 100% degree of knowledge. Examples of formulas to be applied to linear exploration are shown below.

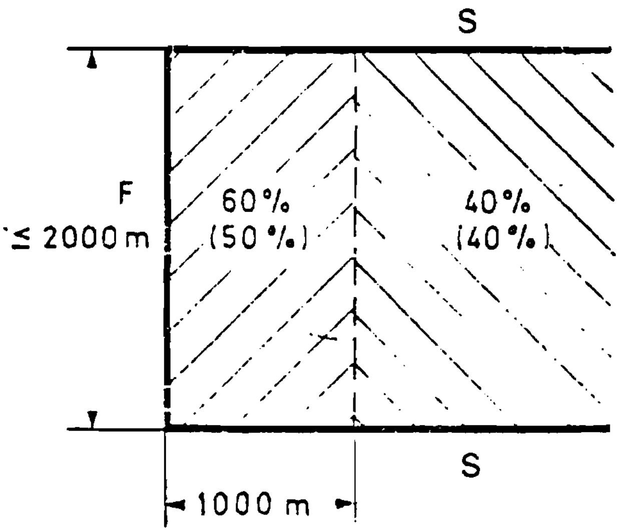
By application of the described formula on the PV results from ZV. After estimate of the development costs for the remaining panels the reserves actually available for production can be calculated and considered for the planning.

Examples for determination of the degree of knowledge

3.2.2 U-shaped exploration to the dip



3.3.1 U-shaped exploration to the strike



Legend: 40 % degree of knowledge, inclination range 0 - 15 gons
20 % " " 15 gons

S = linear exploration to the strike
F = linear exploration to the dip

Scheme: Determination of Reserves

1 = Geologically determined reserves

2 = GV/planning period according to RAG standard definition

3 = Geological residual reserve outside the area covered by the planning period

4 = Selected deposit

5 = According to colliery-specific choice of panels

6 = Abandoned geological reserves (for the planning period AGV)

7 = Reserves to be considered for future layout

8 = According to: Actual layout in known areas
Actual layout in white areas

9 = Layout conditioned losses

10 = Reserves to be considered for production planning

11 = According to empirically determined degree of deserves utilization (according to knowledge of the deposit and seam thickness)

12 = Calculated reduction resulting from expected faulting

13 = Reserves actually available for production (according to colliery-specific choice of panels based on RAG standard assessment criteria)

14 = Calculated reductions according to cost analyses for the individual panels

15 = Plan production (according to production planning)

16 = Not integrated in the planning period

TECHNICAL PROGRESS AND THE SCIENTIFIC-RESEARCH ACTIVITY IN POLISH HARD COAL MINING

Comments on the Problem and Organization of Work in the Forthcoming Years

Wojciech Łakomy

1. Introduction

Discussing the technical progress and research in the Polish underground hard coal mining it is necessary to note that the problem is not tackled for the first time. I would like to refer to the paper "Selected Problems and Research Methods of the Polish Mining Industry Relevant to the IIASA Coal Study" written by J.Stachowicz, W.Łakomy and J.Bendkowski - July 1979 /CP-79-11/.

In this paper many basic data defining the deposit and mines on this exploitation area, as well as, basic problem groups to be solved by scientific-research and construction - - design institutes have been presented. Short outline of the organization of the Polish mining industry and its subordinated enterprises allowed to present the complex management system of this industry. This paper refers to the information included in the above mentioned paper.

2. The role and place of mining industry in Poland against a background of economic situation.

The last decade has been for the Polish mining industry a period of systematic, great increment in production /see table 1/.

Table 1. Development of hard coal output in Poland.

Year	output /thousand Mg/	increment /thousand Mg/	%
1970	140.101		
1971	145.491	5.390	3,8
1972	150.697	5.206	3,6
1973	156.630	5.933	3,9
1974	162.002	5.372	3,4
1975	171.625	9.623	5,9
1976	179.303	7.678	4,5
1977	186.112	6.809	3,8
1978	192.622	6.510	3,5
1979	201.004	8.382	4,4

The increment in production has been achieved mainly by modernization and concentration of the production.

The amount of active mines has decreased from 77 to 66 during the last ten years.

The average output of one mine has increased from 5850 to 9612 tons/day, average output from one mining level - - 2346 to 3743 tons/day, and from one loading point - 643 to 1144 tons/day in this period.

Mechanization of longwall faces and particularly the use of mechanized support, apart from systematic modernization and development of basic technological links in mines /building new levels, shafts, coal preparation plants etc./ have great influence on such considerable output increment.

The length of face front equipped with mechanized support was 2.926 m at the end of 1970 and 56.808 m at the end of 1979.

Output share from this front has increased from 3.0 to 61.1 %.

Those few indices show in short terms the trends of activities connected with such a big output increments. It is necessary to ascertain explicitly that those output increments, did not result from unlimited development possibilities of mining industry, but they were rather constantly extorted by systematic growth in demand of national economy. In such a situation some difficulties and negative facts were inevitable because the requests for quantitive growth of production has come to the fore.

One of such negative facts was engaging the staff during the legal free working days. The so called 4 shift working system has been gradually introduced while searching the methods of restricting the working time for the mining staff unharming the volume of production.

This system ensured the workers regularly two free day after six working days. Due to this, the mines equipped with more and more expensive fittings could work in a continuous mode /24 hours/. Disadvantage of this system was that the free days i.e.

Saturdays and Sundays fell, for particular workers, in the interval of about 6 weeks. This system has not been accepted by the staff and now it is withdrawn from coal mines although the real limited number of working days that is from about 305 to 243 days in a year was obligatory for those working in the 4-shift system.

Another undersirable fact was a gradual changing to the worse of efficiency exploitation index of machines and devices. It was caused by insufficient time needed for everyday maintenance and repair service as well as lack of free days without output, so it was impossible to keep the machines and devices on a desirable technical level.

This fact was a motive to form a considerably big reserve front, and its equipping with expensive mechanized supports caused the reduction of the fixed assets productivity.

The mines which have been forced to accomplish big production increments exerted strong pressure on delivery of new underground machines and devices.

3. Short and long-run needs of the mining industry directed to the mining scientific - research and development base.

Emergencies of the hour caused the necessity of dividing the scientific-research problems into two groups. The first group includes those problems of which development is expected almost on the spot in order to straighten up the irregularity that arose in the past period and also for satisfying the actual needs.

The second group includes problems connected with ensuring correct development of the mining industry in a continuous and harmonious way for a longer period forming at the same time the basis of its safe and economic work.

The first group deals with the technical and organizational preparations within the mining industry for the changing conditions resulting from the introduction of free Saturdays in 1981.
It is assumed that though there will be no coal production on all free Saturdays still the planned annual production cannot be changed. That is why all the coal mines have to be prepared for the new smooth course of work based on a continuous work of the fundamental production links during 5 days and on intensive repair works during two nonproduction days.
Introduction of this system presents many problems that cannot be widely discussed here.

The second group defines the problems connected with the long-term development of the mining industry.

Main stress is laid on a wide scale studies concerning the recognition of the resources of coal seams and the development of the mining regions.

The prospect of mining industry development which will be periodically updated is indispensable.

It includes problems externally conditioned, as well as the resources, technical and organization state of the mining industry.

The mining industry is greatly interested in all the actions tending towards the rationalization of coal and energy consumption.

Although the solution of this problem is beyond the scope of mining industry activity, it is treated as one of the element which diminishes the pressure on the domestic fuel-energy balance in the aspect of the demand.

Works on coal preparation which were conducted on a vast scale many years ago are a very important field of study that needs a long-term activity.

A high technological standard of exploitation has been reached using the method of caving in mining the seams of 0,8 to 4,0 m thickness and dipping up to 35°, and using the filling methods in mining the seams of thickness up to 3,6 m.

75% of coal is mined from faces using these methods.

It is foreseen to continue the works on further improvement of exploitation indices concerning the mechanized supports and heading machines as well as on mechanized equipment for low and edge seam and for efficient exploitation of thick seams using the method of bench mining - both with caving and with hydraulic filled stopes.

The technologies and mechanical equipment for driving the development headings is regarded as an indispensable element of efficient development of exploitation fronts which are characterized by a great progress. It concerns particularly the headings driven in cohesive rock for which construction and implementation of specially made heading machines together with efficient equipment for auxiliary works in gate ends are necessary.

Intensive progress in coal output caused that less pressure has been laid on the problem of coal materials and men haulage. All the problems connected with modernization and improvement of main haulage and many elements of vertical haulage require intensive works of research, construction - design and mining machinery institutes.

The research and implementation of technology and coal preparation devices as well as increasing the production capacity of those devices and automation of preparation processes requires further intensification.
Great production capacity of coal mines require adjusting the mine stations by means of implementing the methods of prompt coal wagon loading.
All the basic natural hazards occuring in the Polish coal mines are the subject of constant studies.

Potential hazard of rock burst, methan and unexpected rock and gas outburst increase systematically due to the transition of exploitation into a greater depth.

The fire and dust hazard are inseparable phenomenon accompanying our mining exploitation.

High temperature and climate conditions underground will become a problem of great concern.
The activity of the whole research base will be directed on a complex suppression of the mentioned hazards which are grounded on:

- the identification of their nature and reasons of origination,
- carrying out the mining activity in such a way as to delimit to a minimum the formation of hazard conditions,
- application of such a control and protection system which would record the growth of hazard and give signals in an appriopriate time,
- application of such prevention means which would allow to avoid dangerous consequences even in case of sudden hazard symptoms.

The above mentioned information does not include all the problems that are going to be the subject of research and development works. It is only a cursory survey of a part concerning these problems.

4. Science projects /programs/ for the needs of the mining industry and organization of their realization.

It is very important to keep up proper proportions between the basic and utilitarian studies in order to give the possibility of using the results in the mining industry. Complex programs are worked out for many problems in the aspect of many years' time horizon treating particular targets in full realization cycle that is starting from the basic investigations /if necessary/ - up to full implementation in the industry.

The coordination plan of each research program includes the period of 5 years, and beside the subject matter of the works, it controls the principles of cooperation with all research industrial enterprises concerned, as well as, the foreseen costs of the studies and the expected results.

The ministry makes a general agreement, for the 5 years period, with an appointed co-ordinator for each co-ordination plan. Financial means for the work realization are assigned in one year instalment. It is indispensable because the plans are not treated inflexibly, and justified changes are permissible.
The payment is covered after the termination of particular targets that can be implemented in practice.

The financial means for scientific - research program realization come in 1/3 from the national budget and 2/3 are created by margins in costs of basic production.

The Ministry is a disposer of these means.
The elements of fixed assets being the result of the research work are either sold to the users at the agreed upon price, or are given gratuitously.
Research works fund covers all the justified risk of unsuccessful solutions or such solutions which for various reasons have not been applied.

DIVISION OF HARD COAL MINES INTO HOMOGENEOUS GROUPS BY MEANS OF TAXONOMY METHODS

Józef Bendkowski
Jan Stachowicz

1. Introduction

Specific features of mining production denote that the production processes are integrally connected with the problems of utilization, first working and panelling of a deposit. Great deal of design - planning activity concerning the preparation of production and modernization is carried out by coal mines.

It is necessary to create the base for the following:

- standardization of performance in the design and planning works and,
- assistance for coal mine services in the above mentioned scope by specialized scientific-research institutes.

These needs caused that the works on defining the similarity and differentiation degree of coal mines according to their numerous differentiated features have been carried out.

Grouping the mines in accordance with their similarity features or differences creates a basis for detailed works in the following scope:

- planning and designing the technical progress,
- improving the management organization,

in homogeneous mine groups.

In the mining literature the regression and correlation calculus is most frequently used for all types of analysis presenting the relations in the form of equations /models/.

Tests of classifying the mines on the basis of criteria concerning the deposit exploitation difficulties as well as technological and organizational criteria depending on the mining - geological conditions have been carried out.

There is a lack of research methods which would explain the problem of technological and organizational development of particular coal mines having regard to the existing achievements closely connected with natural conditions and mine structures.

2. The method of multi - dimensional random variables

A coal mine being a production plant may be characterized by finite number of features /indices/. The value of particular features creates the initial information matrix.

The below multi-dimensional random variable method for a typological mines division based upon the assumend initial information enables to draw the following conclusions in the range of:

- division of coal mines into subgroups within which the statistic inference is more justified than in relation to the whole group,
- definition of relative differences between coal mines.

It has been assumed that N projects /e.g. coal mines/ will be under the observation. Each of these "N" projects is characterized by "m" features /indices/. In the presented mathematical model each project has been assumed as a multi - dimensional random variable.

$$X_j \left(x_{j1}, x_{j2}, x_{j3}, x_{j4}, \dots x_{jm} \right)$$

where: j = 1,2,3, ...) N - represent succesive projects of observation

$x_{j1}, x_{j2}, x_{j3}, \dots, x_{jm}$ - are the features describing the defined project.

Features as initial information for the observed N projects create a matrix in the following form:

$$\left\{ \begin{matrix} x_{11}, & x_{12}, & x_{13}, & x_{14}, & \dots & x_{1m} \\ x_{21}, & x_{22}, & x_{23}, & x_{24}, & \dots & x_{2m} \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ x_{N1}, & x_{N2}, & x_{N3}, & x_{N4}, & \dots & x_{Nm} \end{matrix} \right\}$$

From N set of multi - dimensional random variable values

$$X_j \left(x_{j1}, x_{j2}, x_{j3}, \dots x_{jm} \right)$$

it is possible to form L such groups. There would be no significant differences within each of these groups.

It has been assumed at the beginning that each Xj random variable constitutes a group with a size equal to 1.

Thus L = N that is L group number is equal to N random number at the beginning of the procedure.

For Xj random variable, m - dimensional, examined as m - random dimensional points in m - dimensional space all the possible distance between the groups of variables have been defined in metric space in the following way:

$$d_{kl} = \left[\sum_{i=1}^{m} (X_{ki} - X_{li})^2 \right]^{1/2}$$

In further study Xji co-ordinates of Xj random point have been assumed as standardized quantities.

Among all distances the shortest has been chosen,

$$d_{min}$$

and "p", "q" group numbers have been defined for which d_{min} occurs.

One group is formed from Xp and Xq groups and it receives number 1. It is characterized by an arithmetic mean.

$$X_i^{(1)} = \frac{X_{pi} + X_{qi}}{2}$$

$x^{(1)}$ values define the new variable

$$X_1 \left(X_1^{(1)}, X_2^{(1)}, X_3^{(1)}, \dots X_m^{(1)} \right)$$

which is conventionally called a "mean variable" which has been substituted in the place of a random variable having lower X_{min} /p,q/ index.

The second variable is noted in the data table so that it would not take part in the calculations.

The whole group number is actually diminished by 1 and equals to L = N - 1.

The whole procedure is repeated from the beginning that is, the d_{kl} distance between the groups is calculated; d_{min} is found, as well as the group indices between which the distance is the shortest, then these two groups are joined into a one.

The whole group number is again diminished by 1.
Such a procedure is repeated till the moment when by means of all joints of variables only one group is received or so long when the used test will not cause a break in the grouping process.

During the grouping process three different cases can occur:

1° a new group is created from the elements which till now have not been grouped. Then the procedure is the same as in the first step and the group gets the successive number and a new mean variable is formed. This variable is substituted in the place of a variable having a lower index. The second variable with a higher index is eliminated from the data table.

2° One of the elements of new Gj group is a variable created by the previous grouping process. The new group keeps the previous number. The X_{Gj} mean variable which components are formed as mean components of all variables belonging to this group is calculated:

$$X_{(Gj)i} = \frac{1}{N_{Gj}} \sum_{k} X_{ki} \quad \text{where } X_{ki} \in G_j$$

where: N_{Gj} - size of random variables belonging to this Gj group.

The received X_{Gj} mean variable is substituted in the place of X_{min} /p,q/ with a lower index. The second X max /p,q/ variable is eliminated from the data table.

3° The new group is formed by means of joining the two earlier created groups. In such a case it retains the lower number and the numeration of all the other groups is changed so that the sequence of numbers would be retained. This new group is characterized, as previously, by a mean variable which components are a mean value of components of all variables forming this group. For variables of a new created group the distance from the centre of the group is calculated i.e.

$$d_{(G_j)k} = \left[\sum_{i=1}^{m} (X_{ki} - X_{(G_j)i})^2 \right]^{1/2}$$

where: k - adopts numbers of random variables belonging to the disscussed group.

On each step of the grouping process the intergroup variance of $\tilde{\sigma}^2_{mq}$ distance is calculated

$$\tilde{\sigma}^2_{mq} = \frac{1}{L-1} \sum_{j=1}^{L} N_{G_j} \left| X_{(G_j)} - \bar{X} \right|^2$$

where:

$$\bar{X} = \bar{X}(\bar{X}_1, \bar{X}_2, \bar{X}_3, \ldots \bar{X}_m)$$

$$\bar{X}_i = \frac{1}{N} \sum_{j=1}^{N} X_{ji}$$

$$\left| X_{(G_j)} - \bar{X} \right|^2 = \sum_{i=1}^{m} \left| X_{(G_j)i} - \bar{X}_i \right|^2$$

thus:

$$\tilde{\sigma}^2_{mq} = \frac{1}{L-1} \sum_{j=1}^{L} N_{G_j} \left| X_{(G_j)i} - \bar{X}_i \right|^2$$

Intragroup variance of $\tilde{\sigma}^2_{wq}$ distance has the form of

$$\tilde{\sigma}^2_{wq} = \frac{1}{N-L} \sum_{j=1}^{L} \sum_{k=1}^{N_{G_j}} \left| X_{(j)k} - X_{(G_j)} \right|^2$$

that is

$$\sigma^2_{wg} = \frac{1}{N-L} \sum_{j=1}^{L} \sum_{k=1}^{N_{aj}} \sum_{i=1}^{m} \left(X_{jki} - X_{(aj)i} \right)^2$$

The calculated values of intragroup and intergroup variances allow for testing a hypothesis of equality centres of the created groups, i.e.:

1/ zero hypothesis Ho

$$\sigma^2_{mg} = \sigma^2_{wg}$$

2/ alternative hypothesis

$$\sigma^2_{mg} > \sigma^2_{wg}$$

Calculating the value of the variable

$$F = \frac{\sigma^2_{mg}}{\sigma^2_{wg}}$$

one can compare it with F_{α} quantity according to Fisher - Snedecora tables on α significance level by

$S_1 = L - 1$ and $S_2 = N - L$

degree of freedom.

In case of $F \leqslant F_{\alpha}$ it can be stated that there are no reasons for rejecting the Ho hypothesis which assumes that the co-ordinates of the group centres do not differ from each other in a statistical significant way. It indicates the homogeneity of a set which has been formed from these groups. If $F > F_{\alpha}$ then the accepted hypothesis should be rejected because the intergroup deviations are beyond the limit, assigned by the spread, but within of the tested material.

3. Preparation of the statistical material

In order to unify the influence of choosing the measurement units of particular features the standardization of those features has been carried out by means of the following formula:

$$\hat{X}_{ik} = \frac{X_{ik} - \bar{X}_k}{S_k}$$

where: X_{ik} - values of k - coordinates for
i - variable
$i = 1, 2, \ldots, N$;
$k = 1, 2, \ldots, m$;

$\bar{X}_k$ - mean value of k coordinate

S_k - standard deviation of k co-ordinate

The selected indices /features/ should, in the best way, characterize the essential coal mine potentialities with regard to the studied problem.

In calculations described here the following initial quantities have been defined.

They characterize the following elements in the hard coal mine -

- engineering - technological subsystem,
- social subsystem,
- organization subsystem.

The data have been collected or calculated for all deep hard coal mines /65 mines/.

These quantities have been described by means of independant features as follows:

A. <u>Engineering - technological subsystem</u>

- output
- share of output from longwall faces with mechanized support in the following:
    - total output
    - output from faces

- inwestment outlays
- gross value of fixed assets
- mean seam dipping
- mean height of stoping face
- mean depth of exploitation
- mean length of working front
    - total
    - daily
- mean daily advance from:
    - longwall with caving
    - longwall with filling
    - web
- mean temperature in stoping faces
- intensification of development works
- mean daily entry advances of:
    - rock heading
    - rock-coal heading
    - coal heading
- water inflow to a coal mine
- shifts

B. Social subsystem

- general productivity
- mean wages
- employment in industrial group
    - workers
    - production engineers
    - clerical employees
- employment in non-industrial group
- absenteism of workers in the industrial group

- time of working at the face
- the number of employed people who improve their professional qualifications in total,
    - post graduate course
    - university studies
    - secondary school
    - elementary technical schods
    - others
- employment of engineers
    - working underground
    - working on the surface
- employment of technicians
    - working underground
    - working on the surface
- the number of people employed in a mine who act as teachers of profession
- fluctuation index
- reasons of fluctuation /discharges from a coal mine/
    - too dangerous work
    - too strenuous work
    - few chances of getting a flat
    - bad work organization in the sections
    - few perspectives of getting a promotion
    - few possibilities of acquiring or improving professional qualifications
    - low wages
    - frequent overtime work
    - work on Sundays and holidays
    - work incompatible with the qualifications

- impossibility of passing to another section or different type of work
- bad treatment by fellow - workers
- bad treatment by the viewers
- other reasons
- the index of managerial staff training.

C. <u>Organization subsystem</u>

- the degree of working by the piece,
- grading
- management range
- accumulation of management apparatus
- usage of the qualifications of the engineering staff
- standarization of the operational information links
- function universalization
- extraformal patterns of organization activities
- formalization of description of line executive role
- relative quantity of supporting elements
- extensiveness of structure activity
- sporadicity of program - controlling procedure
- the scope of program - report procedures
- the scope of role specialization
- deconcentration of competence centralized horizontally
- non-formalized rythm of executive procedure.

4. Discusion of results of calculations

65 coal mine divisions have been obtained for successive degree of freedom from 1 to 65. In the final specifications of calculated results for each division the following information has been given:

- values of intergroup distance variance
- values of intragroup distance variance
- F value /according to pattern 10/.

F values have been compared with F_α /taken from the tables - Fisher - Snedecora distribution/ on $\alpha = 0,05$ significance level taking into account the degree of freedom

$$S_1 = L - 1$$

$$S_2 = N - L$$

in order to check the significance of received divisions. The given algorithm enables the observation of the elements and subsets displacement and joining into homogeneous typological groups. Intervals differentiated in subset homogeneity i.e. division 1 representing typological groups which are more homogeneous then division 2 etc. have been distinguished for each analysis basing on statistical test.

The significant measurement of typological division of hard coal mines set is a value of the F variable ratio to F_α quantity. The optimum division has been gained by satisfying the following condition

$$\frac{F}{F_\alpha} = \max$$

for defined $S_1 = L - 1$ and $S_2 = N - L$ degree of freedom.

Assuming the production results for 1979 i.e. the mean coal output per one working day, the following division of mines can be done:

- output up to 6000 t/day - 11 mines
- output from 6000 - to 10000 t/day - 27 mines
- output from 10000 - 15000 t/day - 19 mines
- output above 15000 t/day - 8 mines

For the optimal division the following distribution has been obtained:

typological groups / sub-systems	I					II		III				IV				V				unidentified - one element			
	a	b	c	d	a	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
engineering technological	-	8	7	4	4	6	3	2	4	3	1	3	9	-	-	1	1	3	-	1	2	-	-
social	2	11	3	-	5	9	1	2	7	3	4	1	3	4	1	1	2	-	2	-	-	-	-
organization	1	6	5	4	6	4	2	2	4	3	1	2	9	7	1	-	-	-	-	-	1	-	-

- for the whole system

typological groups / systems	I					II		III				IV				V				unidentified - one element			
	a	b	c	d	a	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
system as a whole	-	9	7	4	2	3	3	4	4	2	1	3	-	3	-	2	5	3	-	-	2	1	-

In groups the number of coal mines has been given depending on the size i.e.

a/ up to 6000 t/day
b/ from 6000 t/day to 10000 t/day
c/ from 10000 /day to 15000 t/day
d/ above 15000 t/day

Division 2 and 3 equal to the local F/F extreme values and being a characteristic indirect stage needed for obtaining the optimum division is presented below.

typological groups / sub-systems		I				II				III				IV				unidentified one-element groups			
		a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
engineering-technological	2	–	5	2	3	4	8	7	2	2	6	6	2	3	5	4	1	2	3	–	–
	3	1	4	3	2	5	13	5	1	3	9	10	5	–	–	–	–	2	1	1	–
social	2	2	11	4	1	4	2	5	3	2	3	2	3	1	10	6	–	2	1	2	1
	3	3	9	2	2	3	5	5	4	2	2	7	2	2	7	3	–	1	4	2	–
organization	2	–	7	4	3	3	6	2	2	5	7	6	3	3	3	5	–	–	4	2	–
	3	–	6	3	3	4	5	8	4	6	10	5	1	–	–	–	–	1	6	3	–

– for the whole system

typological groups / systems		I				II				III				IV				V				one element groups			
		a	b	c	d	[illegible]	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
system as a whole	2	–	8	2	2	[illegible]	3	5	2	3	5	2	3	3	4	5	–	2	3	4	1	1	4	1	–
	3	–	7	2	1	[illegible]	6	7	1	4	7	6	3	2	5	3	1	–	2	1	2	2	–	–	–

Basing on the carried out studies of which some results are presented in the above tables the following can be stated:

- there is a strong differentiation of coal mines not only as an economic system as a whole, but also within their components of subsystems and coal mine size. Traditionally it has been assumed that the size of a coal mine has been measured on the basis of output volume as initial variable differentiating the approach to the designing and planning processes.

  The results of these studies negate this thesis because many different factors influence these differentiation. There was an attempt to calculate the importance of these factors according to the following mathematic procedures:

    - factor analysis,
    - main Hotteling components.

  It lays under necessity of finding another solution concerning the designing, organization and management problems based on the system and contigency approach.

- The studies on the degree of differentiation of particular subsystems i.e. engineering - technological, social, organization of individual coal mines indicate far greater differentiation than mine differentiation being a system consisting of the above mentioned elements.

Final conclusions

Defining the strategy of a coal mine development i.e. the selection of succesive mutation of exploitation technology, production organization, management system development /including the definition of forecasts in the scope of work efficiency, developing the methods of forming the required organization climate/ requires a differentiated approach in relation to different mines, or at least to differentiated classes - coal mine groups.

In our opinion the initial step in the planning and design works would be the definition of mine homogeneous group according to their numerous features.

Selection of features describing the mines should be subordinated to the requirements of the system approach.

It is necessary to distinguish 3 classes of features describing engineering-technological subsystem /including also mining - geological conditions of a deposit/, organization and social subsystem.

The presented here method meets the above mentioned requirements i.e. it includes 20 features of engineering-technological mine system, 16 features of organization system and 22 features of social system.

However, the used mathematical statistic methods allow for an objective, consistent with the assumed degree of accuracy division of mines into homogeneous classes.

The next step of this work, in the aspect of planning and design is the definition of prognosis, plans etc. for different complexion of mine's activity and for successive homogeneous classes.

At present, for example, we conduct works on the development of prognosis in the field of efficiency, evaluation of organization level and development of strategy in the scope of improving the organization and management in selected mine classes.

These works, as well as, the presented method carry into effect the first and the second stage of studies submitted by the Polish party as their contribution to IIASA's works within the "Coal Issues for the 80-s" project. /1/

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[1] J.Eddington, J.Stachowicz, R.Tomlinson. Report of the Inaugural Meeting for an IIASA Collaborative Industry Study. IIASA. Working Paper. 79-44. June 1979.

APPLICATION OF HEURISTIC METHODS IN INNOVATION PROCESS OF TECHNOLOGY AND ORGANIZATION OF LONGWALL MINING

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I. Introduction

The necessity for steady increase of hard coal output in the period of next 20 to 30 years puts before Polish mining industry and its managing and technical staff difficult tasks both actual and future with medium and long time horizon.

It results from the essence of the coal mining technology that parallelly with the improvement of current production should be specified the conceptions of the future.

The necessity for working out a forecast of mining development results also from the need for preparation of appropriate level of technique, organization and economics basing on expected possibilities of obtaining solutions in the range of fundamental research.

The Main Bureau of Study and Mining Designs made in the period of 1967 ÷ 1968 a thorough study of two time horizons for the level of technical solutions in the future hard coal mine, namely:

1. "mine of the future" designed and realized in the period of 1970 + 1985,
2. "mine of the year 2000" designed and realized in the period of 1985 + 2000.

The authors of these conceptions assumed two time horizons: 1985 and 2000.

In the first time interval they forecast designing and realization of so called mine of the future. The prospects of mines development in that period were as follows:

- maximum concentration of mining work,
- intensification of extraction by great progress of faces,
- suitably great progress of development work,
- use of loading points with capacity of 5000 to 8000 tons/day, thoroughly mechanized and automated,
- full mechanization of all processes in mine taking advantage of different mechanized machine complexes of new design,
- use of remote and automatic control of machines and installations,
- introduction of conveyor transport underground (from face to shaft) or of heavy rolling stock between loading points and shaft.

The solution of the above problems was to be enabled i.a. by introduction of:

- high-speed driving roadways by means of newly designed complexes,
- general use of machines and installations for great-diameter drillings,
- special methods of supporting narrow workings,
- complex automation and mechanization of getting processes,
- introduction of mining by new complexes with controlled capacity,

- improvement of stowing material,
- getting coal for full flow.

For the model of the "mine of the year 2000" a development was assumed distinguishing two principal mine conceptions:

1. working in order to win electric energy,
2. working for the purposes of chemical coal processing.

It has been assumed that the deposit would be mined without extraction of the gotten onto the surface.

From the developed deposit will be obtained e.g. the electric energy by application of new technologies without old mining method.

In the mine where deposits will undergo chemical processing, it was foreseen that extraction methods will be used consisting in washing out or diluting the deposit or in its gasification. The mine will constitute a homogenous mining-energetic or mining-energetic-chemical industrial group.

Perspective models of mines are also presented by L. Pluta. Referring to the hard coal mines he presents the development of mines beginning from production groups built up of integration of mining areas of operating mines and ending with industrial fuel and gas producting groups. He gives final technical indices depending on the degree of mechanization and automation. With complex automation following configuration of them is foreseen:

output from a face, Mg/day - 2500
output from a section, Mg/day - 4000+6000
mine production, Mg/day - 25000
kind of organization at face - permanent operation
kind of organization of mine - changes on stands of control supervision

The author describes the conceptions of underground fuel producing and energetic industrial group whose general assumption is the location of energetic plant at the working level in the place of actual shaft bottom. A further step is the model of mines conceived for the needs of fuel producing and energetic industrial group over and underground in which power plants are integrated with installations for coal gasification under pressure.

The author postulates the development of exploitation of methane deposits by openings method as getting ahead mining of hard coal deposits.

The authors of the presented conceptions did not draft, however, the characteristic development phases of extraction technology from the actually used to the perspective ones which makes a gap in the forecast of development of technology and organization of longwall mining.

II. Justification of research work in the range of development of mining technology

In the hard coal mining industry problem determining the improvement of production efficiency is rational utilization of available material means.

The outlays for equipment of longwall complexes grow rapidly which is dictated by the necessity of securing indispensable increase of productivity with keeping safe conditions during extraction, particularly of thick and deeply lying seams.

In the period of last decade the bulk of outlays for equipment of longwall face increases rapidly to reach a value exceeding as much as 300 mln zł at faces equipped with imported shield supports.

Characteristic phenomenon in the structure of outlays is the decreasing share of value of the getting and loading machine. The structure of outlays born for equipment of a longwall 180 m long depending on type of supports is as follows:

with Valent supports - 7,873,000 zł including value of cutter-loader for 38.1 %

with SHC supports - respective values are 11,207,000 zł and 26.29 %

with PIOMA 25/45 supports - 98,016,000 zł and 3.49 %

The actually used technologies do not take full advantage of potential possibilities of existing machines and installations as well as of available working front.

The investigations carried out into prognostic tendencies of technical progress in the hard coal mining and the recognition of needs for appropriate innovations extended by keen studies indicate the advisability of development of research work in order to work out new efficient and reliable methods of mining coal seams.

Particular attention in this way, in the horizon of the next 10 to 20 years, should be paid to practical and organizational mastering of the technology of longwall mining by continuous method whose initial development stages are multiple cutter-loader mining teams.

Therefore following thesis has been formulated:

THERE IS PRACTICAL POSSIBILITY FOR INCREASING OUTPUT PER UNIT OF SURFACE OF PRODUCING FRONT THROUGH APPROPRIATE COMBINATIONS OF KNOWN AND ACTUALLY DESIGNED EQUIPMENT.

For realization of this thesis following purposes have been assumed:

1. Determination of the set of prognostic solutions of technology of multiple cutter-loader mining of longwalls.

2. For selected prognostic classes of mining technologies assessment and rationalization of techno-organizational parameters of these solutions together with analysis of their reliability and efficiency.
3. Formulation of tendencies in development of technology and organization of longwall mining with statement of practical postulates and proposals for designers and constructors of mining machines.

III. Prognostic solution of multiple cutter-loader mining methods

The objective of the work was being achieved in successive considerations and particular testings including i.a.:

- prognostic investigations,
- morphological analysis,
- successive verifications of generated solutions,
- initial practical assessment of solutions recognized as satisfactory and rationalization of techno-organizational parameters of these solutions.

The working method is shown on Fig. 1.

In prognostic and innovation investigations heuristic methods were used, particularly for elaboration of new solutions. One of many heuristic methods is the morphological analysis used in order to find new solutions of problems which had already before certain solutions recognized, however, as unsatisfactory.

When formulating morphological table the fundamental distinguished processes have been divided into phases - operations defined by the subset of technical means.

The distinguished processes and their constituent phases have been summarized in Table 1.

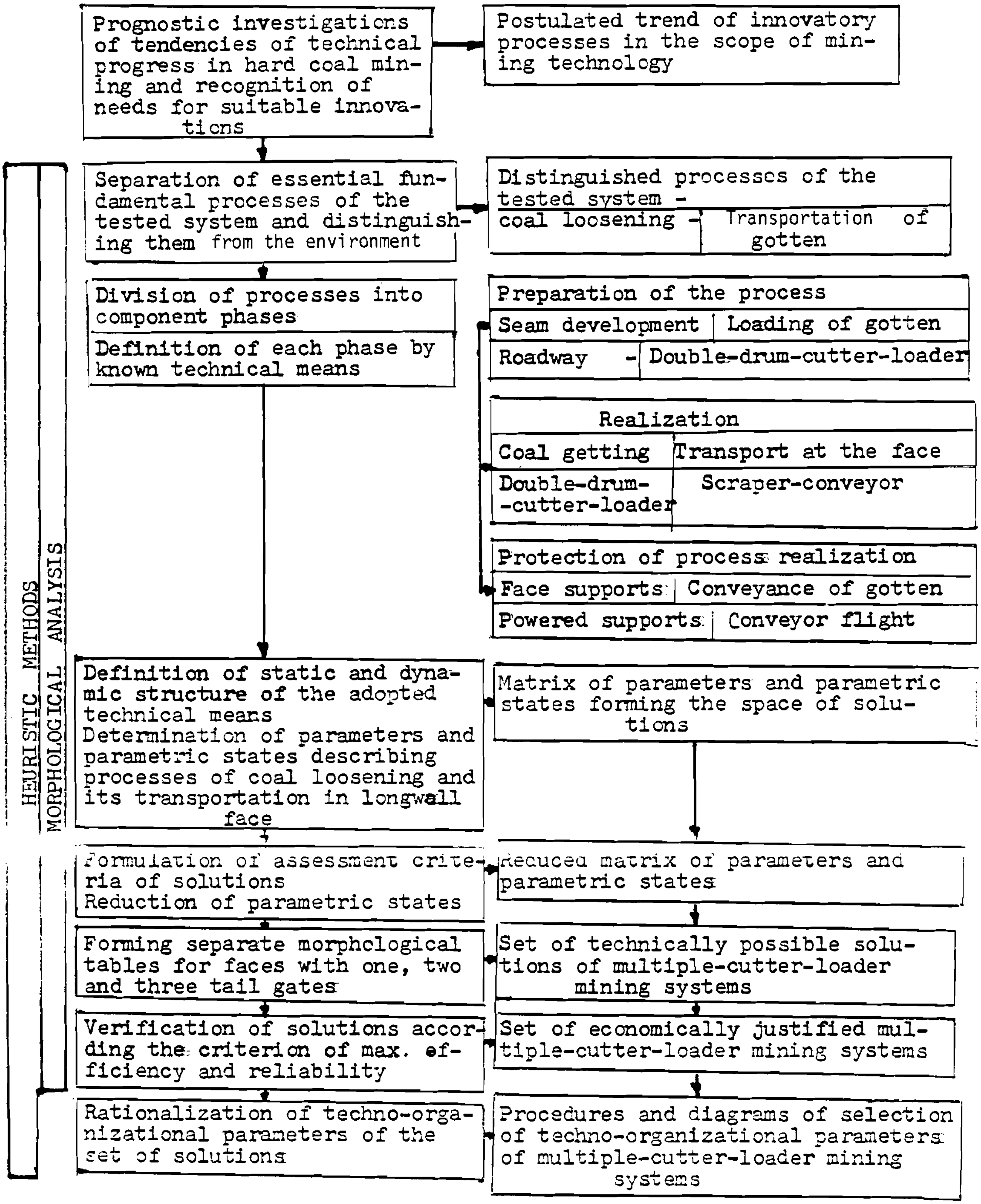


Figure 1. Working Method

Distinguished processes and their constituent phases

Table 1

Distinguished process	Phase	Technical means
Loosening	Development Getting Kind of supports	Roadway Drum-cutter-loader Powered supports
Transport	Loading Transport at the face Transport outside the face	Drum-cutter-loader Scraper conveyor Scraper conveyor + belt conveyor flight

By determining static and dynamic structure of adopted technical means 24 parameters have been defined, characterizing the processes of loosening and transportation of the gotten. Each parameter is then described by independent irreducible states. The set of parametric states represents in the adopted limits the whole of means necessary for attainment of prescribed characteristics of solution.

The space of solutions is built by the matrix of parameters and parametric states.

The individual variants of solutions are obtained by combining whichever state from each line.

The number of solutions obtained in this step exceeds the possibilities of assessment and that is why with allowance for the adopted criteria of productivity and reliability the number of parametric states has been reduced.

Deduction of contradictory combinations reduces the number of solutions, but that is still a number which renders difficult finding of innovatory solutions.

To obtain distinct classification of solutions three successive morphological tables have been set up, separately for faces with one, two and three tail gates, Fig. 2.

The obtained set of technically possible solutions including:

- 10 variants of mining with one tail gate,
- 57 variants with two tail gates and
- 18 variants with three tail gates

have been verified allowance being made for criteria of maximum efficiency and reliability, which gave 24 solutions of multiple cutter-loader mining methods recognized as satisfactory in the aspect of the assumed thesis.

Representative examples of these solutions are shown in Fig. 3.

The solutions recognized as satisfactory include faces limited by extreme tail gates in which getting is effected by cutter-loaders working on at least two independent face conveyors.

It is assumed that cutter-loader or cutter-loaders working on one conveyor make together with this conveyor a mining team.

The minimum length of the mining team is determined by the minimum length of stall while the maximum length of the former by the maximum length of conveyor.

In order to obtain actual data characteristic for the mining process testings have been carried out in the Powstańców Śląskich mine in the longwall with caving 161 m long and 3.5 m high equipped with powered supports, KWB 3RDS cutter-loader and Rybnik 73 conveyor.

In spite of relatively advantageous production results oscillating about 3000 Mg/day only 45 % of available time were utilized for coal getting and 27 % for loading in return (manoeuvring) motion.

Fig. 2. MORPHOLOGICAL TABLE OF METHODS OF MINING COAL SEAMS IN LONGWALL /STALL/ FACE

Face equipment: sectional powered supports, double drum jib cutter-loader

A. With one tail gate

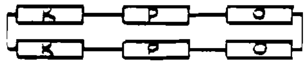
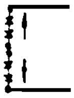
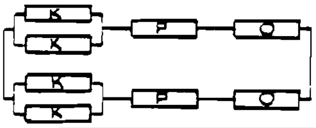
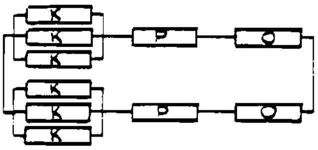
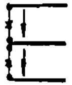
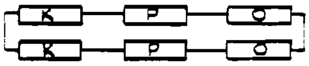
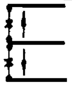
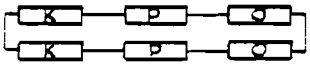
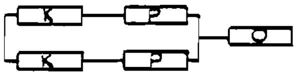
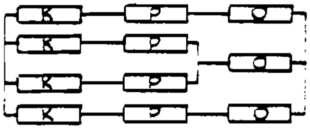
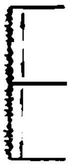
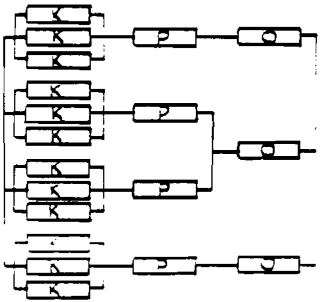
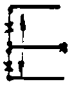
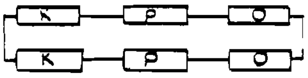
Parameter	Symbol	Parametric state				
		1	2	3	4	5
Tail gate	a	Executed before mining as extreme and maintained	Executed before mining as extreme and liquidated	Executed with determined advance as extreme and maintained	Executed together with the face as extreme and maintained	Executed before mining as central and liquidated
Number of cutter-loaders on conveyor	h	one	two	-	-	-
Number of face conveyors	r	one	two	-	-	-

B. With two tail gates

Parameter	Symbol	Parametric state					
		1	2	3	4	5	6
Tail gates	a	Extreme executed before mining	Extreme, one of them executed before mining another driven with advancement	Extreme driven with advancement and maintained	Extreme, one of them executed before mining, another driven with advancement	Extreme driven together with longwall and maintained	Executed before mining one as extreme, another as central
Number of cutter-loaders on conveyor	h	one	two	three	-	-	-
Number of conveyors	r	one	two	three	-	-	-
Direction of conveyance	w	one	two	-	-	-	-
Location of outside-face conveyors	x	in one extreme tail gate	in two extreme tail gate	In central tail gate	In central and extreme tail gates	-	-

C. With three tail gates

Parameter	Symbol	Parametric state			
		1	2	3	4
Tail gates	a	Extreme ones and central one executed before mining	Extreme ones executed before mining, central one with advancement in relation to the front line	-	-
Number of cutter-loaders on conveyor	h	one	two	three	-
Number of conveyors	r	two	four	-	-
Direction of conveyance	w	one	two	-	-
Location of outside-face conveyors	x	in extreme tail gates	in extreme and central tail gates	In central tail gate	in extreme and central tail gates

NO	DIAGRAM OF ARRANGEMENT	DIAGRAM OF CONNECTIONS OF ARRANGEMENT ELEMENTS	LENGTH OF FACE	PRODUCTIVITY INDEX	NUMBER OF MINING TEAMS	NUMBER OF CUTTER-LOADERS	NUMBER OF CONVEYOR FLIGHTS	NUMBER OF ELEMENTS
1	2	3	4	5	6	7	8	9
0			$L_{min}=32$ $L_{max}=L_{pmax}$	W_{tI}	1	1	1	3
II.4			$L_{min}=64$ $L_{max}=2L_{pmax}$ $L_{opt}=128$	$2W_{tI}$	2	2	2	6
II.5			$L_{min}=128$ $L_{max}=2L_{pmax}$ $L_{opt}=198$	$2W_{tII}$	2	4	2	8
II.6			$L_{min}=192$ $L_{max}=2L_{pmax}$ $L_{opt}=256$	$2W_{tIII}$	2	6	2	10
III.1			$L_{min}=64$ $L_{max}=2L_{pmax}$ $L_{opt}=128$	$2W_{tI}$	2	2	2	6
III.4			$L_{min}=64$ $L_{max}=2L_{pmax}$ $L_{opt}=128$	$2W_{tI}$	2	2	2	6
III.7			$L_{min}=64$ $L_{max}=2L_{pmax}$ $L_{opt}=128$	$2W_{tI}$	2	2	1	5
III.13			$L_{min}=128$ $L_{max}=4L_{pmax}$ $L_{opt}=256$	$4W_{tI}$	4	4	3	11
III.15			$L_{min}=384$ $L_{max}=4L_{pmax}$ $L_{opt}=512$	$4W_{tIII}$	4	12	3	19
III.16			$L_{min}=64$ $L_{max}=2L_{pmax}$ $L_{opt}=128$	$2W_{tI}$	2	2	2	6

○—✕—○ – MINING TEAM
——► – DIRECTION OF CONVEXANCE
—— – TAIL GATE
——✱ – CENTRAL TAIL GATE DRIVEN WITH ADVANCEMENT
[K] – DOUBLE-DRUM-CUTTER-LOADER
[P] – FACE CONVEYOR
[O] – CONVEYOR FLIGHT

TECHNO-ORGANIZATIONAL PARAMETERS OF CHARACTERISTIC SOLUTIONS OF MULTIPLE CUTTER-LOADER MINING SYSTEMS

FIG.3

The motion parameters of cutter-loader are as follows:

getting velocity $V_u = 1.919$ m/min
loading velocity $V_m = 3.269$ m/min

$$\frac{V_u}{V_m} = 0.587$$

medium productivity of cutter-loader = 2.842 Mg/min.

For assessment of prognostic technologies the conception of productivity index has been introduced which is defined as quotient of potential - theoretically possible - output in web cycle and production capacity of one cutter-loader with characteristics identic as characteristics of cutter-loaders used in longwall

$$W_t = \frac{Q_{sc}}{Z_{kc}}$$

The productivity indices lettered for one-, two- and three-cutter-loader teams respectively as W_{tI}, W_{tII}, W_{tIII} have been analytically defined for mining teams working in longwalls higher than the diameter of getting organs, i.e. for longwalls of medium for Polish mining heights of getting. In such conditions jib double-drum cutter-loaders are used. Analysed have been teams:

- with one cutter-loader as variant BI
- with two cutter-loaders as variant BII,
- with three cutter-loaders as variant BIII.

The characteristic feature of the analysed mining methods is essentially unidirectional getting and loading of the remaining gotten on the way back (manoeuvring motion).

The index W_t for individual variants is a function of length of mining team and of relation V_u/V_m the increments of value of this index decreasing with increase of the team length. Forming of productivity indices W_t depending on the length of team calculated for values $V_u/V_m = 1, 1/2, 1/3, 1/4$ have been presented on Fig. 4.

From analysis of variation of the index W_t a conclusion was drawn that rational - with regard to the productivity criterion - is the length of the n-cutter-loader team if it equals the minimum length of the n+1 - cutter-loader team.

In the present paper by reliability of element is meant the probability of performing by the element under pre-determined conditions, in pre-determined period, the required objective function. For working conditions of face technological systems it is defined as ratio of the working time of the element to the sum of times of work and standstills forced by unserviceability of this element in pre-determined time interval.

In technological systems used so far principal elements make up series connections:

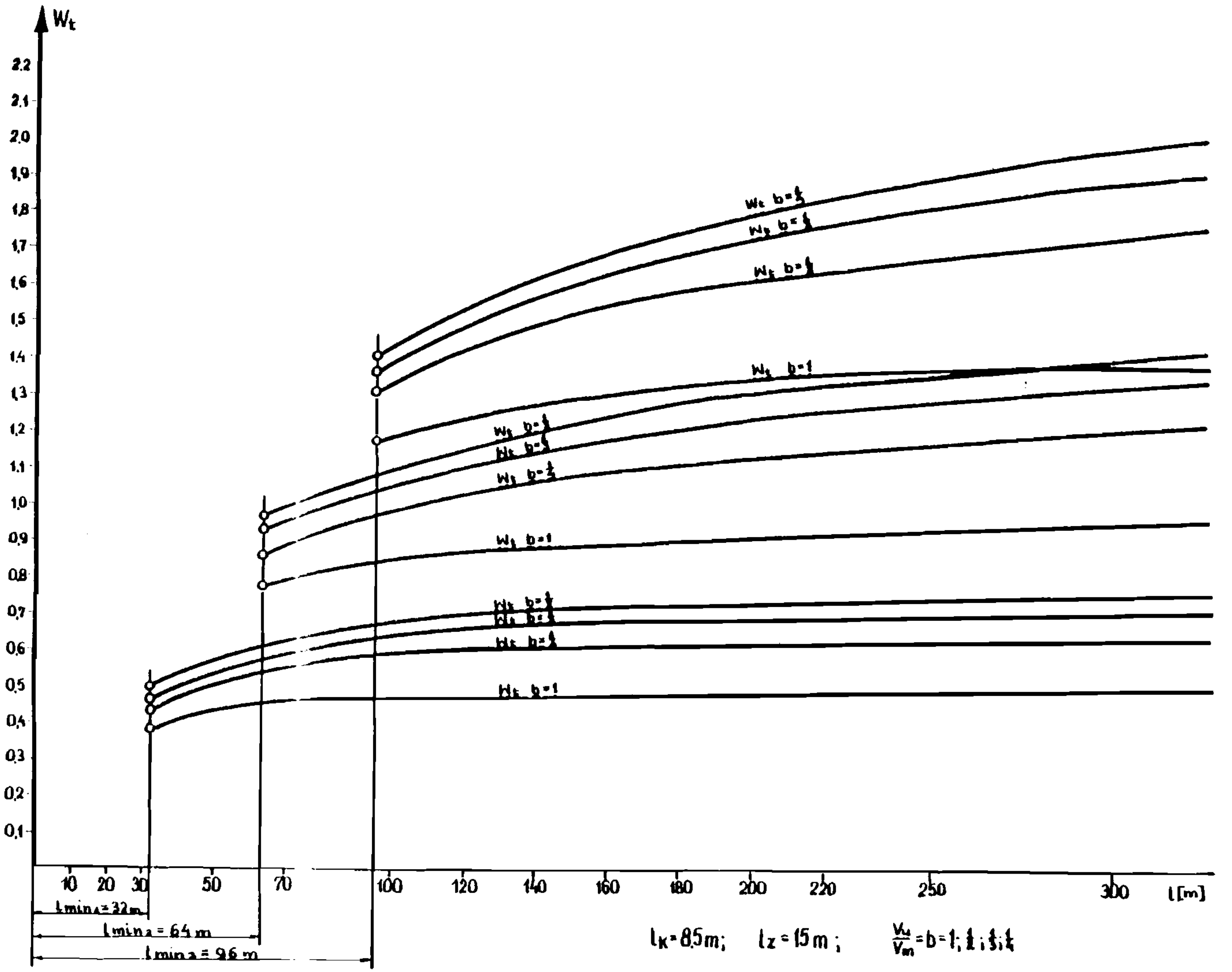
cutter-loader - longwall conveyor - outside-face conveyance

the Rg index varying from 0.60 to 0.75. So, the arrangement of elements of which every one is characterized by relatively high reliability makes a whole of low readiness index.

By much higher reliability are characterized arrangements with parallel connection of elements.

The reliability index of arrangement can be reckoned on the basis of determined tests of anticipated readiness indices of individual elements.

This is, however, a not too precise procedure for prognostic solutions considering structural changes, progressing improvement of workmanship and other factors affecting the reliability level. In this situation the assumption has been adopted that with increase of number of elements of the system - cutter-loaders, face



$l_K = 8{,}5\,m$; $l_Z = 15\,m$; $\frac{V_u}{V_m} = b = 1;\ \frac{1}{2};\ \frac{1}{3};\ \frac{1}{4}$

VARIATION DIAGRAM OF W_t INDEX

FIG. 4

conveyors and conveyance flights - with mixt connections but prevailing parallel ones the reliability of the systems increases.

The statement of characteristic parameters and connections of selected solutions is presented on Fig. 3.

The set of solutions in the system productivity index - number of elements has been shown on Fig. 5.

The considerations pertaining to the meters of assessment of efficiency of longwall work differ from those used so far in this range in the fact that they take into account the reliability of technological system and the productivity measured by degree of utilization of cutter-loader possibilities.

Moreover, particular solutions are characterized by:

- number of mining teams,
- length of a mining team,
- number of cutter-loaders,
- number of conveyance flights,
- way of connection (co-operation) of individual elements of technological system.

In the final stage procedures and diagrams have been worked out of selection of techno-organizational parameters of seams extraction in following decision taking situations requiring;

1. determination of technological system assuring maximum production - Fig. 6.
2. selection of system assuring the most advantageous techno-organizational indices in the limited panel - Fig. 7.
3. selection of system assuring the attainment of required production level - Fig. 8.

In economic analysis extraction costs have been compared of a panel with dimensions 180 x 1200 x 3.2 m if mined by conventional method with face equipment with powered sectional supports type

FIG.5

NUMBER OF FUNDAMENTAL ELEMENTS OF TECHNOLOGICAL SYSTEM	RELIABILITY INDEX ↑	W_{tI}	W_{tII}	$2W_{tI}$	W_{tIII}	$2W_{tII}$	$4W_{tI}$	$2W_{tIII}$	$4W_{tII}$	$4W_{tIII}$
19										III.15
18										
17										
16										
15										
14										
13										
12										
11							III.13			
10								II.6		
9										
8						II.5				
7										
6				II.4, III.1 III.4, III.16						
5				III.7						
4										
3		○								

PRODUCTIVITY INDEX →

SET OF SATISFACTORY SOLUTIONS IN THE SYSTEM
PRODUCTIVITY INDEX W_t TOWARDS
NUMBER OF ELEMENTS

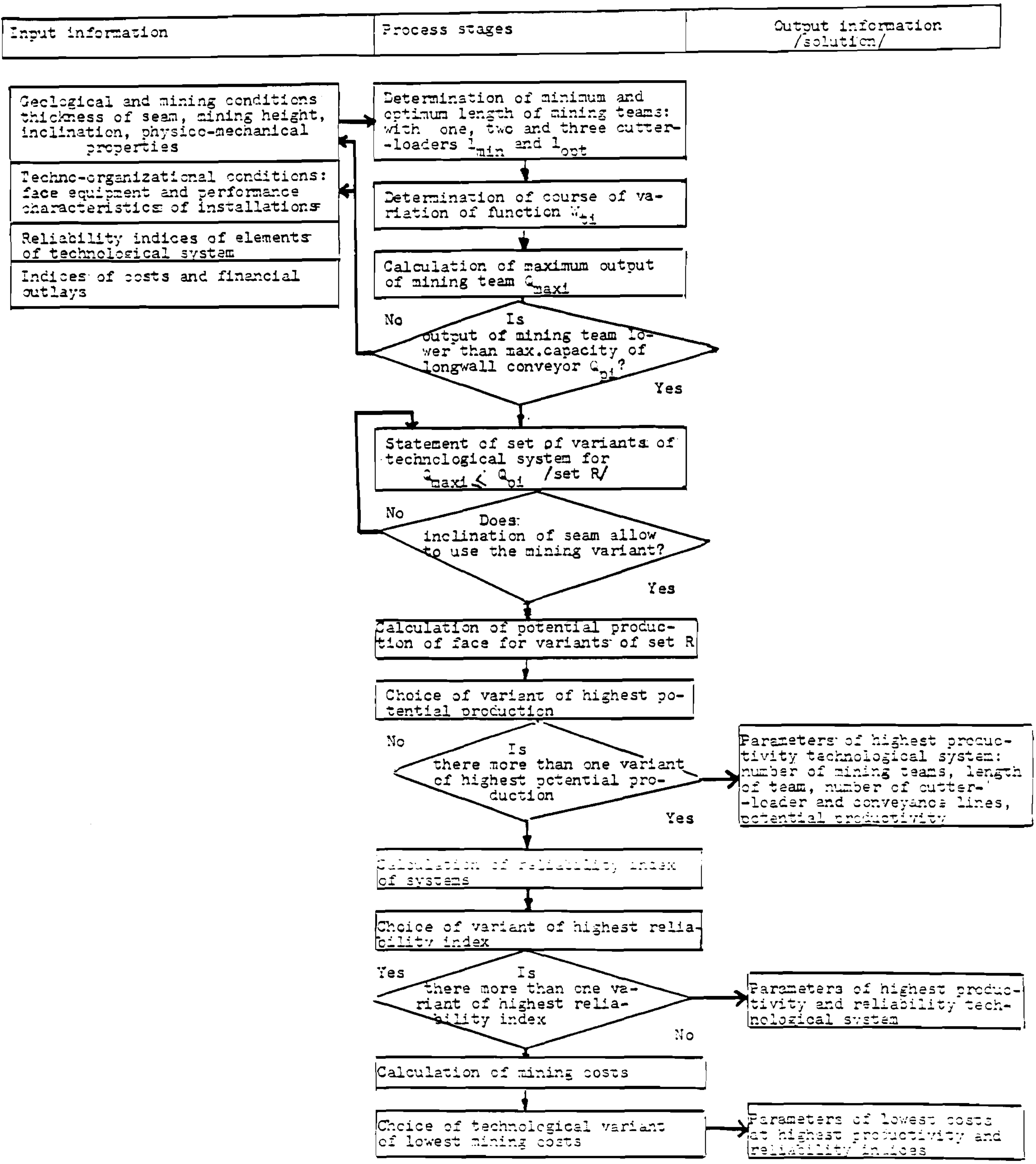


Figure 6. General Diagram of Selection of Highest Productivity Technological System

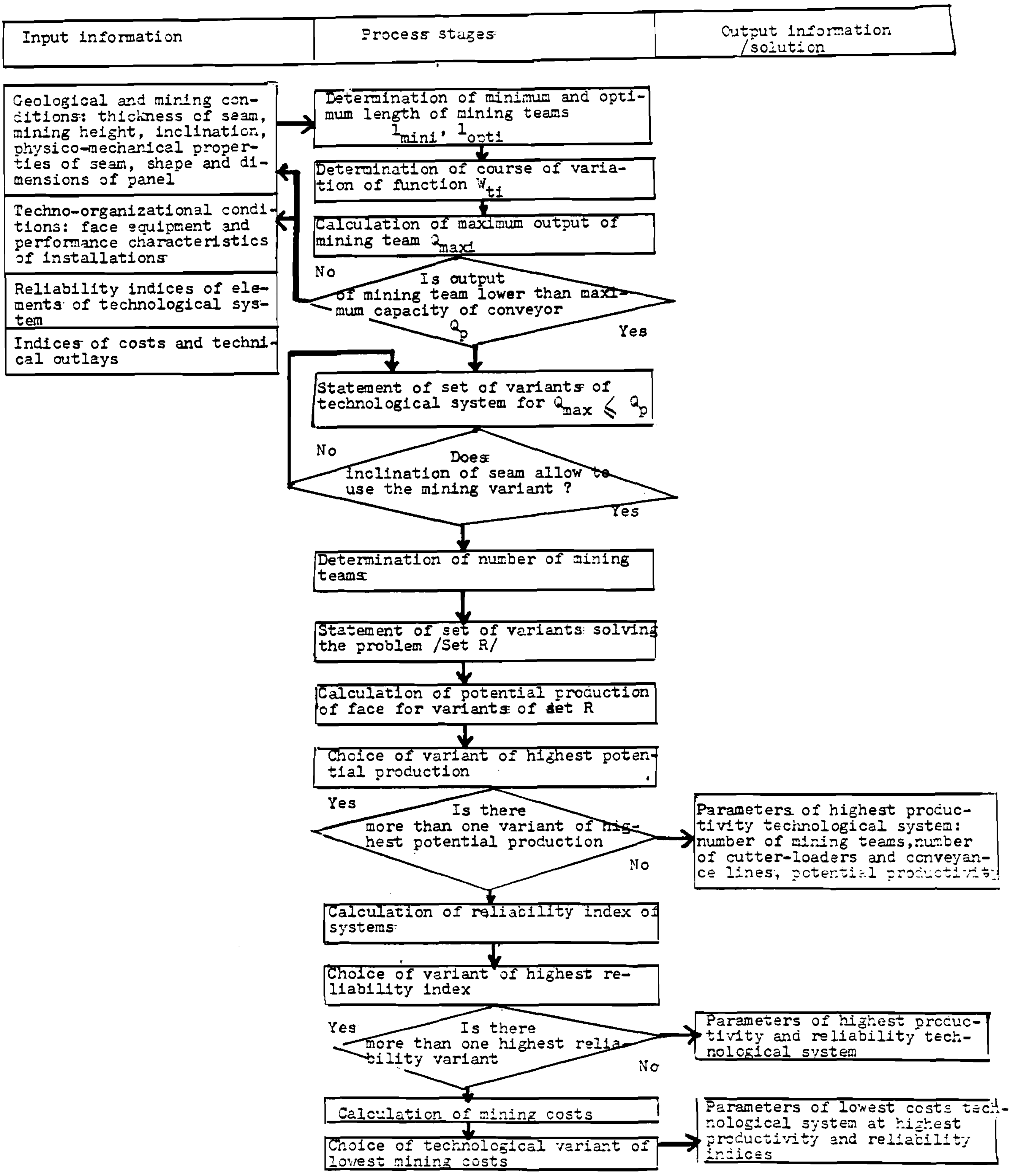


Figure 7. General Diagram of Selection of Highest Productivity Technological System for Limited Panel

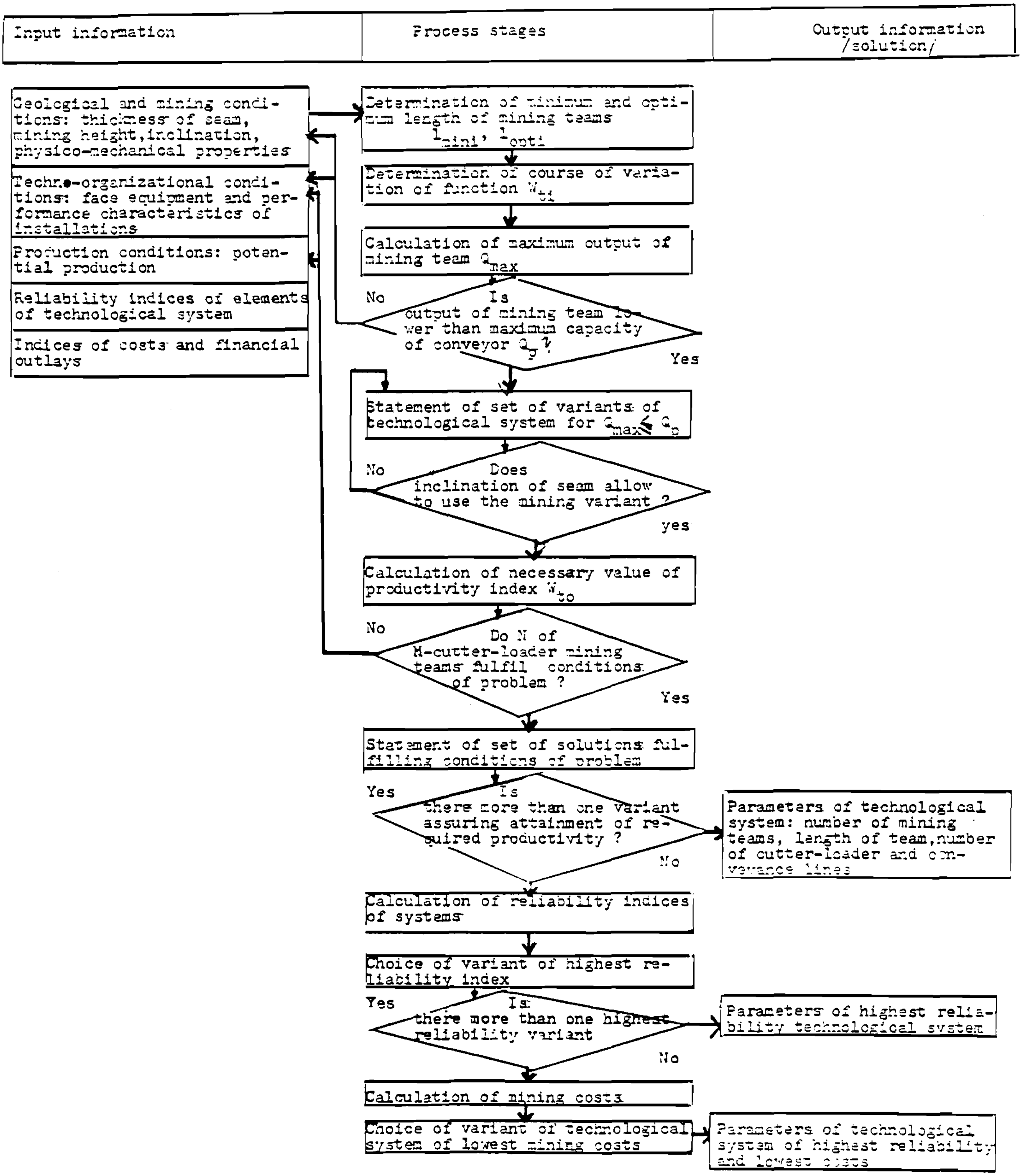


Figure 8. General Diagram of Selection of Technological System and Panel Dimensions for Predetermined Productivity Panel

FAZOS, KWB 3 RDS cutter-loader, Rybnik 73 conveyor and mined by technological system according to variant III.13. Application on this front of four one-cutter-loader teams assures:

- about triple increase of production,
- reduction of mining costs by 10 mln zł i.e. by 11.85 zł on each ton won from this panel,
- increase of mining progress from 4.4. to 14.1 m/day,
- shortening of the mining period from 273 to 85 days.

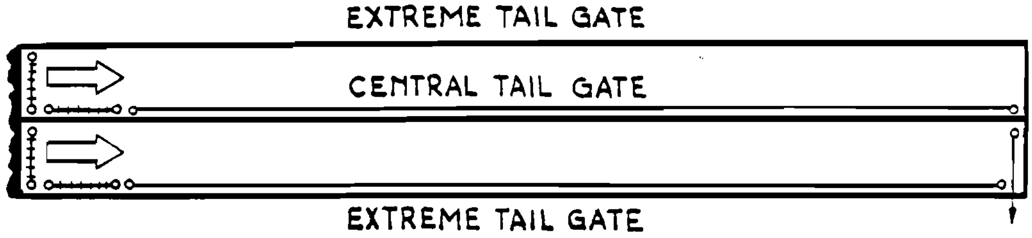
In faces with shield supports the benefits grow in consequence of limitation of high amortization costs charging the production.

The carried out calculations give the practical confirmation of advisability of utilizing the set of variants. In order to obtain appropriate compactness and clarity of elaboration simplifications have been introduced in analytical stage and in synthesis resolving themselves into cases of using exclusively mining teams of equal number of cutter-loaders and also into consideration of cases of mining with caving along the line of seam strike.

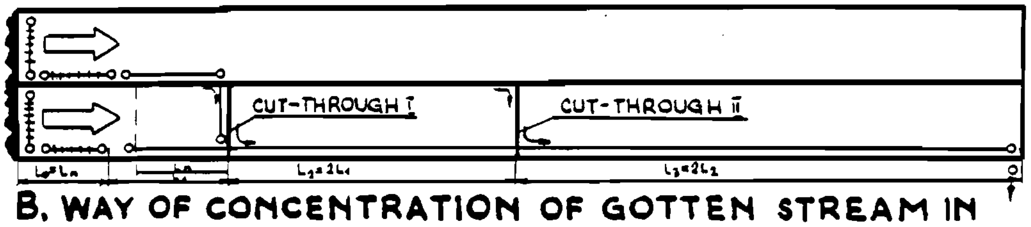
In design situations under determined geological, mining and technical conditions other mining systems may be used - combinations of mining teams of different productivity levels assuring the highest level of output and reliability.

In case of using three tail gates - in spite of evident benefits indicated in the economic analysis - justified to all appearance can be the resistance against building very long parallel flights of conveyors for outside-face haulage. In such situation the reduction of haulage costs can be attained through concentration of the stream of gotten on one of flights.

Examples of solutions for two and three conveyance lines have been shown on Fig. 9.



A. TRANSPORT OF GOTTEN IN PARALLEL ROADWAYS - SYSTEM USED TILL NOW



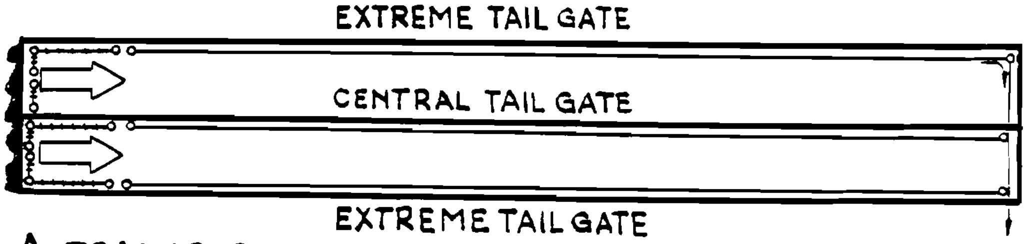
B. WAY OF CONCENTRATION OF GOTTEN STREAM IN ONE TAIL GATE

I PHASE - GOTTEN FROM CENTRAL TAIL GATE IS DIRECTED BY CUT-THROUGH I TO THE EXTREME TAIL GATE

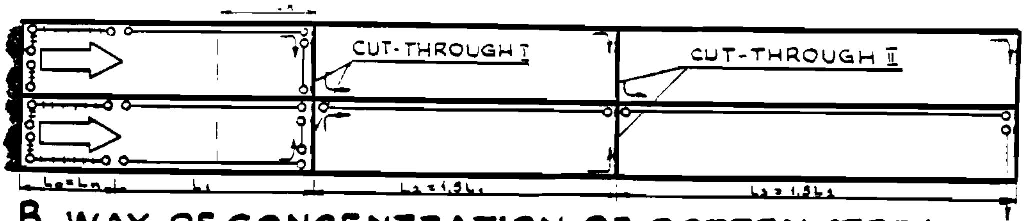
II PHASE - ANALOGOUS OPERATION USING CUT-THROUGH II

L_n - WIDTH OF THE ZONE OF OCCURRENCE OF INCREASED STRESSES

PANELLING EXAMPLES FOR TWO PARALLEL CONVEYANCE FLIGHTS



A. TRANSPORT OF GOTTEN IN PARALLEL ROADWAYS - SYSTEM USED TILL NOW



B. WAY OF CONCENTRATION OF GOTTEN STREAM IN CENTRAL TAIL GATE

I PHASE - GOTTEN FROM EXTREME TAILGATES IS DIRECTED TOWARDS CENTRAL TAIL GATE BY CUT-THROUGH I

II PHASE - ANALOGOUS OPERATION USING CUT-THROUGH II

o+++++o SCRAPER CONVEYOR o——o BELT CONVEYOR ——► CONVEYANCE DIRECTION

PANELLING EXAMPLE FOR THREE PARALLEL CONVEYANCE FLIGHTS

PANELLING EXAMPLES FOR TWO AND THREE PARALLEL CONVEYANCE FLIGHTS

FIG. 9

FINAL CONCLUSIONS

1. The actual technologies of mining hard coal seams do not assure optimum utilization of factors participating in the production process: not utilized remain the production possibilities of supports and of developed mining front. The indicated faultiness deepens with increase of height of face.

2. Using the morphological method a set of prognostic solutions has been attained which assures the increase of degree of continuity of mining coal from longwall. It has been ascertained that suitable connections of known elements of technological system - roadways, cutter-loaders, face and outside-face conveyors - rendered possible manifold increase of productivity and reliability of the work at face.

3. The highest efficiency and reliability of the work at face is attained in the case of using four n-cutter-loader mining teams and correspondingly high number of conveyance flights. In the case of using the actually existing installations the most advantageous is use of four one- or two-cutter-loader teams and three conveyance [illegible]. Such a system requires appropriate development work - two extreme tail gates and one central tail gate. The existing installations and machines connected in technological systems according to prognostic variants enable the obtention of an output of 5000 to 10000 tons/day from a production face of a length not exceeding 200 m. The examples indicated the high efficiency of proposed solutions. A limitation for the number of cutter-loaders is the capacity of conveyors.

4. The diagrams of selection of techno-organizational parameters of technological systems developed for the method can be utilized in practice when designing new mines and new horizons and also they can be useful for need of planning production in mine. The indicated possibilities of manifold increase of production falling on unit of front length should contribute to more rapid increments of output in mines being in the stage of construction. Similar effects may be attained also in panels with complicated tectonics, strongly inclined or of low width.

5. The utilization of solutions will make sure about bringing the concentration indices nearer to the maximum values and in consequence of their implementation a decided improvement will be attained of economic indices of hard coal mines. The increase of concentration degree will effect also simplification of spatial structure of mine. Use of mining teams - in alternative series connections - on a relatively short front makes up a model of mine of very high elasticity and reliability. This is particularly important for keeping the proper rythmical pace of production.

6. The development of multiple cutter-loader mining methods requires execution of a number of investigations for which the subject has been given by way of example in the present paper.

POLISH EXPERIENCE IN OPERATION RESEARCH APPLICATION FOR PLANNING OF MINES AND MINING REGIONS

Eugeniusz Ciszak
Andrzej Mazurek

1. Introduction

The use of computers has enabled to introduce methods of applied mathematics and to utilize a great number of quantitive and qualitative information for designing purposes.

The computer analysis has been used in the Polish mining industry for several years.

All planning and designing problems in Poland related to underground coal mining /excluding coal preparation plants/ are solved by the Chief Mining Studies and Design Office at Katowice being a national multi-branch institution.

The implementation of computer techniques in mine designing began in 1971 by the use of various routine methods for structural analyses of mine surface objects. Currently, Operation Research is used in all stages of the mining design works, i.e. in:

- programming the mining sector's development
- feasibility studies and feasibility reports for development of individual mines and mining regions
- detailed technical designs
- supervision of construction works on the building site.

The ranges of calculation programs are adjusted to the individual stages of the planning and designing process and to the various elements of the investment project. In coal mines, there exists a direct correlation and feed-back between the work results of individual production sections and the production processes. Therefore, from the viewpoint of systems research, in the pursuit of the establishment of the most suitable structure and size of the system it may be a considered advisable to assume a mine as a single big system which in its whole should be examined in all relevant aspects.

This may be achieved by the implementation of computer techniques but the optimization analyses of bis systems, and particularly of such complex systems like mines, are very difficult to be performed; thus it has been suggested to carry out disaggregated analyses of the separate sub-systems and to look for partial optima. However, the sum of the partial optima usually is not equivalent to the global optimum of the whole system.

A still greater number of problems arise if the development of a new coal basin or a new coal region in planned.

To make a time - and - space connection between assumptions of development of the mining industry and the regional planning, the following problems /inter alia/ are to be considered and solved:

- optimum utilization of the coal deposits and accompanying minerals
- development of the regional infrastructure in terms of service centres, welfare centres, transport and communication networks, water-supply network and sewage disposal system, energy sources and distribution, etc.
- development of the associated industries, particularly those that are traditionally connected with the region
- development of the education establishments for various levels and faculties/ and creation of work-places for various occupational groups
- environmental protection.

The application of the information science in designing and office works is a separate problem: in this connection, a computerized information retrieval system "INCALIDO" has been developed and introduced. This system enables to gather information data on selected study and design works carried out in the regional planning and design offices situated in different parts of the country.

A simple arrangement of descriptors enables to obtain a quick and selected information on a required problem or design. Fig. 1 presents a graph showing the processing mode and information retrieval system.

2. Programming the sector´s development

A planning approach to the development of the mining sector is included in the feasibility studies and reports prepared for the Ministry of Mining. On the base of these studies and reports, the long-term plans are developed.

In this regard, programs are used where the profitability of the scheme is the objective´s criterion. The profitability is calculated by means of processsing of the input information for various multi-variant solutions. The most efficient programs in this scope are:

Optimization system of development of the coal mining industry

This system consits of two basic parts. The first part includes multi-variant optimization of development of individual coal mines which are analysed within the program, the second part aims to optimize the complex development program for the coal mining sector.

On a given stage of deposit´s exploitation, and taking into account coal demand projections, the system indicates the most advantageous variant /from the point of view of the whole economic efficiency of the sector/ for the individual coal mines. In the variant, the increase or decline of the coal output in each mine is taken into account, together with the lead times and ways of the program´s implementation. The general block diagram of the said program is shown in Figure 2.

Programs for calculation of natural deposit´s parameters

These programs enable to estimate the coal resources and coal reserves in the coal deposits for optional depth intervals and to determine the basic model of a coal mine and its horizons. The programs are destined to carry out the resource analyses in the prospective coal mining areas which have been explored exclusively my means of boreholes, as well as in the areas of existing collieries, including: protective pillars, bed outcrops, fault lines, degree of geological exploration, etc. In the coal resources and coal reserves classification, apart from the optional depth intervals and seam thicknesses, ten other at will selected deposit parameters /e.g. ash and sulphur content, type of coal, the coal heating value/ are accounted for. The programs were used practically several times, and particularly for planning the new Lublin Coal Basin, to selve such problems as: division of the deposit into coal mining areas, depth of mine horizons, location of shafts, etc.

Programs for calculation of rock body and surface deformations

These programs enable the projection of the deformation indicator values for separate stages of mining exploitation, adjustment of the exploitation effects to the resistance of structures and control of mining panels arrangement in order to minimize the negative effects of exploitation upon the surface.

3. Feasibility reports for construction of coal mines

Computer methods applied in the elaboration of feasibility reports for purposes of collieries construction enable the

execution of multi-variant techno-economic analyses accomodated to the specific mining and geological conditions.
The most frequently used programs are the following ones:

Mathematical model of a single-horizon mine

This model enables a selection of most advantageous design schemes of the mine underground and surface on the basis of economic criteria, according to the given natural conditions. Consequently, a physical model of a mine the XXX-universary colliery in the Rybnik Mining District, has been determined on the ground of optimization calculations, significant reduction of capital expenditure was achieved.

Program for the optimization of dimensions of a mining area

This program was adapted to the conditions prevailing in the Lublin Coal Basin. It enabled:

- the estimation of economic effects of mining area dimensions and the selection of most favourable mining area sizes
- the comparison of effects of various mechanization and automation levels for mining
- the comparison of economic effects of the variable amount of coal output from a longwall face and from the whole mine
- the comparison of the effectiveness of various possibilities of the opening-up and development of . coal deposits.

The model of the deposit development, determined as a result of optimization calculations, has contributed to a significant reduction of production cost per 1 ton of coal

Optimization system for the determination of the working horizon structure in a coal mine

The system solves the following problems:

- the size of exploitation panels at a horizon
- selection of the most adequate variant of the deposit's development system at a given horizon
- determination of the optimal timinig of the panels exploitation at analyzed horizons
- for analyzed development systems, indication of parametres which characterize the working horizons structure.

Fig. 3 shows the simplified graph of the program operation. As the optimization criterion, the minimum unit cost of coal production in the mining panels has been assumed.
The unit production cost includes preparatory work, coal exploitation and closing - up of coal mining in separate portions of the coal deposit.
The program makes it possible to reduce significantly the exploitation cost at the planned horizons.

4.- Detailed designs

At the stage of detailed designs, calculation programs are used for construction works. Consequently, the design engineer obtains a number of technical data which enable a more reasonable use materials, workings and plant equipment.
At this designing stage, calculation of capital expenditures or production costs are not always included in the programs. There some programs may be useful which are used at the preliminary designing stage, e.g. the program for reserves estimation and optimization of the mining area.
The most frequently used construction and technological programs are:

Software package for the static and dynamic calculations of surface and underground structures of collieries.

The set includes a dozen or so of systems and calculation programs, where particularly important are the following ones:

- dynamic calculations of block foundations under non-percusive machines
- dynamic calculations of headframes and shaft towers
- static and dynamic analysis of flat bar arrangements and stumpy frameworks
- static analysis of construction roof grates and grillage foundations
- static analysis of three - dimensional layouts
- analysis of foundations and underground storeys of building subject to underground exploitation effects.

The above-said systems and calculation programs are based on theoretical considerations which enable to design mining structures including a number of interrelations and factors which cannot be introduced withoud a computer. The said methods have been implemented in the designing of many mining structures, such as industrial buildings on colliery surfaces, underground lining; winding vessels /cages and skips/; apartment and social buildings, and mining ancillary structures.

In paralled with the large scale implementation of the above methods in the coal mining industry many analyses and calculations have been carried out and which have been utilized for design works in other branches, such as steel industries/e.g.the industrial structures for Katowice Steel Plant/, building engineering /houses and municipal buildings in mining areas/, health establishment /Medical Centre at Ochojec/, the engineering industry /supporting structures for boilers/, power industry /foundations under high-capacity turbine sets/.

Programs for ventilation calculations

These programs include two problems:
analysis of the ventilation systems operation and of the atmospheric conditions in the underground.

The programs related to the first problem make it possible to determine the parameters of fans operation in co-operation with the ventilation network, and to analyze the air distribution scheme at normal operation conditions and in various emergency situations.
The analysis of atmospheric conditions includes the comprehensive calculations of air temperature in the whole air network /or in parts thereof/ and in blind ends which are aired by air tubes, as well as the selection of air conditioners and determination of the operational parameters.

Programs for hydraulic stowing calculations

They lead to the determination of parameters of the hydraulic stowing installation and the diametres of pipes which form the underground hydraulic stowing system. They indicate the size of stowing bunkers on the surface and their operational characteristics.

Program for optimization of a mechanized longwall face

The program presents the technical equipment of a longwall face and allows to carry out calculations of the longwall width and of the advance distance, as well as of the amount of coal output, daily rate of advance, and O.M.S. so as to achieve in the prevailing mining and geological conditions, the lowest production cost of mining.

Program for calculation of water drainage system

On the basis of calculations, the following main drainage parametres are obtained: the size of the underground water reservoirs, required pumps efficiency, velocity of the liquid flow in the pipelines, thickness and weight of the pipes, selection of pumps and motors.

Optimization of the rail and belt - conveyor transport system

On the basis of simulating the r.o.m. coal transportation process, optimization calculus is carried out in respect of:

- capacity of the u.g. bunkers situated within the panel and at the shaft bottom
- efficiency of the main transport equipment
- number of the u.g. rolling stock or belt conveyors parameters for various alternatives of organization of the transport operation.

The use of the transport simulation systems enables to reduce the total capital expenditures by about 5 percent.

The software package relative to communication engineering

The package embraces basic design calculations referring to

- the railway stations throughput
- the earth moving works for the construction of railway lines and roads and for site levelling
- the geometric layouts of railway stations and roads
- the greatest rain water run-off from the catchment area
- the railway transport system on the colliery surface.

Programs for strength calculations of winding plant elements such as: skips, cages, braking devices, as well as calculations for licence - obtaining are often used. Also programs may be mentioned which calculate power distribution systems and low-tension networks as well as sanitary and central heating systems. In the environment protection programs for the calculations of air dustiness caused by the mine boilers, for noise propagation and for the determination of environmental protection zones are used.

5. Construction supervision at the building site

By order of the investors, the design offices carry out mine construction supervisions at the building sites. The programs which are used here are based on the network methods which make it possible to determine the critical path for the construction of a structure, or of a set of structures. Besides, the time-schedule analyses and analyses of the utilization of basic materials and equipment are carried out.

This mode of investment activity makes it possible to shorten by about 10 % the lead time, so that the output objective can by attained earlier.

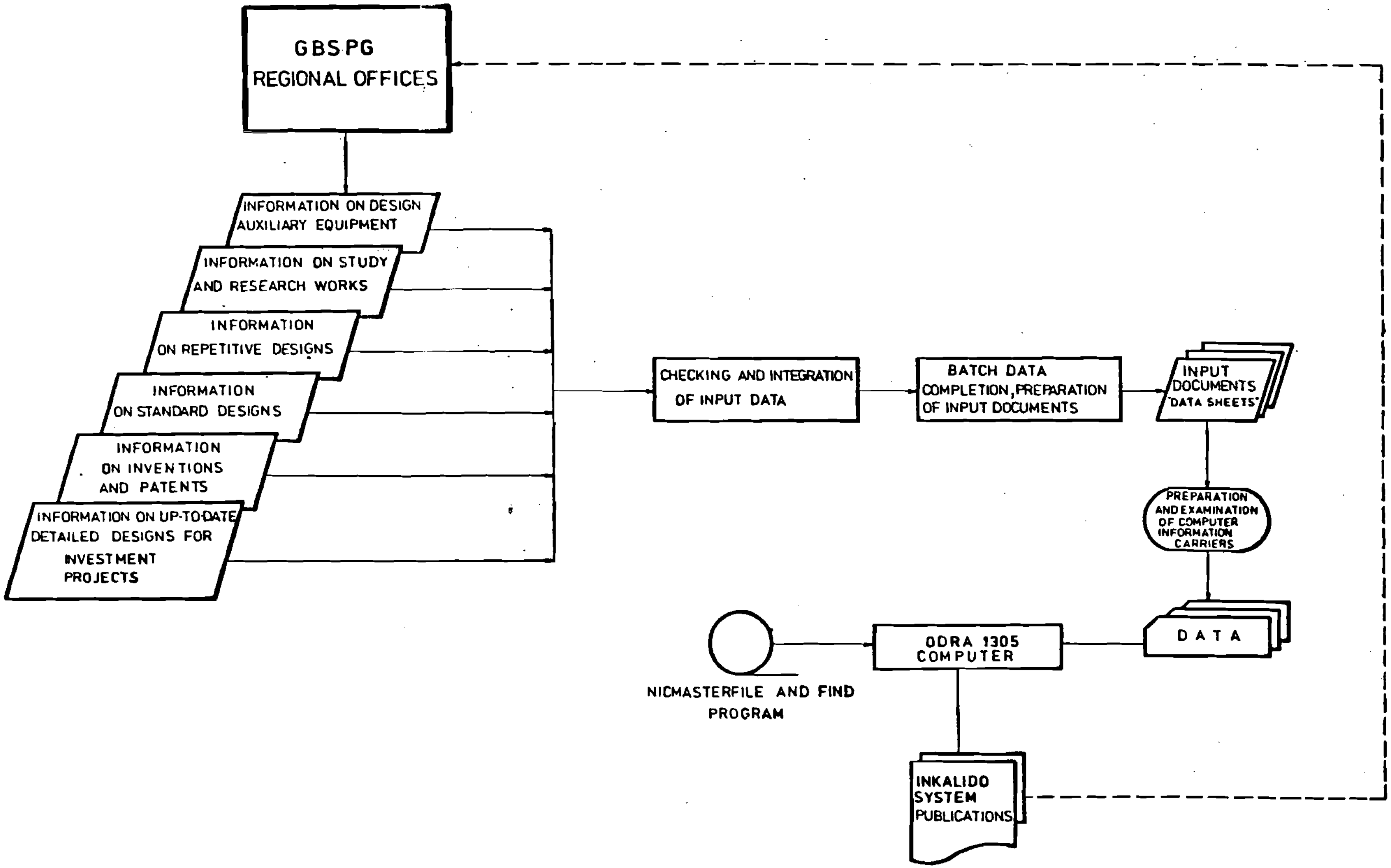
9. Summary

The digital computing methods are used in the everyday designing practice with regard both to planning the complex development of the coal deposits and to separate designing objectives. The interdisciplinary examination of the solutions includes achievements of theoretical disciplines, scientific research works and experience of engineering practice.

On the basis of many years of practice, further progress in digital computing methods is projected by means of the development of hardware in the computer centre /graphoscopes and alfascopes, geographic outlets/ and quantitive and qualitative expansion of works in software. In this connection, the digital computing system supporting the designing activities through out the whole mine designing period, and in all designing sections, will be constantly improved and implemented in practice. The transportation from the method of batch

data processing to the system of dialogue between the designer and computer should improve the efficiency of the electronic computing techniques used in mine design works.
The significant expansion of the scope of actions performed automatically by computers is foreseen.
It will cover the elaboration of all design documents, including the stage of detailed design. The elaboration of such systems has already been undertaken and it would be useful if it could be made a subject of multilateral international co-operation between the design institutions interested in such problems in various countries.

GRAPH SHOWING PROCESSING AND STRUCTURE OF THE AGGREGATED SET OF THE INKALIDO SYSTEM



SIMULATION--REGRESSIVE METHOD FOR ANALYSIS OF COAL MINES CONSTRUCTION AND DEVELOPMENT VARIANTS

Dr. Antoni Madejski

1. Introduction

Decisions making with reference to the future activities of economic units is as a rule preceded by preparing alternative development directions. Alternative desings have in view the estimation of effectiveness of various design solutions at some defined external and internal conditions. The principle of preparing various development alternatives is generally recognized in the process of hard coal mines prospective development planning. In practive, however, a quite essential obstacle in widening the scope of variants for individual development intentions of mines, appears in a high laboriousness of bring in use [illegible] and methods [illegible]. At the same time, the traditional analytic methods being applied for assessment of mines development variants indicate generally low, not exceeding a dozen or so percent, oscillation of those assessments elements /e.g. unit costs of production/ in a wide range of variant design parametres values [5]. The results do not conform to observations drawn from the coal industry, frequently indicating at appearance of considerable differences in economic results of production, even if the mines operate on deposits having similar geologic conditions.

The paper presents the mines development variants assessment method, developed in Polish coal mining in the recent few years, in which the use is taken of coupling the simulation method of future mine investment and production processes in computer reproduction with the generalization method of the current technoeconomical experience gathered by mines in a form of regression functions of many variables. Author of this paper is one of the chief authors of the essential solutions and designing methods [8], [13] . A group of over a dozen people worked on the software and activating this method for several years.

The method presented in the paper is implementable by means of SPP.1 software package [13] , having its prototype in SAWIP program developed and implemented already by 1966-1969 for the purpose of simulation analysis of single horizon mines constructions and production development [1]. The SPP.1 program package has been developed for ICL 1904 and ODRA 1305 computers.

The basic programs of the SPP.1 package have been developed and implemented already by 1970-1972. Within the period 1974-1979 the SPP.1 package was implemented all together for analyzing the development variants for over twenty coal mines [4], [9].

Further, the paper characterizes the method of simulative-regressive assessment of mines development variants, fun[illegible] package SPP.1, the results of the hitherto applications of the method are also presented in this paper.

2. Data on mines development variants designed for analysis.

Concept of future mine development, drawn by designers, forms the basis for simulative analysis carried out by means of the software package SPP.1. In accordance to the references [3] and [13] the concept first of all covers the scheme of opening the separate deposit blocks at separate mining horizons.

The deposit blocks make fragments of a mining horizon including in the vertical cross-seams. Boundaries of the deposit blocks are conventionally established by the adopted deposit opening scheme as also in a natural way by possible major faults, protective pillars lines or by mining boundaries. Seam portions occurring in deposit blocks are further on called the exploitation panels.

The planned deposit opening scheme is presented in a form of so called technological network. Opening scheme presented on the network should include only the location of opening workings without determining their construction time. So arranged technological network is of use to the designer to present the scope of opening works for the specific deposit blocks. Moreover, the technological network serves the purpose of indication of transport and ventilation routes. Therefore, in case of active mines, the transport and ventilation gateways already finished and serving some deposit blocks under operation are indicated on the technological network as well. Lengths and cross-sections of individual elements of the technological network are required to be determined by the designer in order to assure that while analysing the mine variant by SPP.1 software package the calculations of range of mining works necessary for opening the specific deposit blocks will be carried out, as also of transportation routes lengths and the air flow capacities of ventilation ducts. Some other construction operations e.g. in connection with extensions of surface plants might be also presented on the technological network. For the technological network having such elements, as the desing data are given the time and cost of theirs execution.

List of surface objects complexes to be constructed together with their technological characteristics may be alternatively presented apart from the technological network in a respective primary /basic/ document.

Exploitation panels specified in particular deposit blocks are characterrized by industrial reserves, seam thickness, type of coal, methane content and also by the anticipated exploitation system, by output concentration from single exploitation face and by average distance between exploitation face and the loading point. The last three factors are the indicators for technological standard in exploitation panel. Technological standard of the other production links is determined by a limited number of such indicators as the capacity of mining tubs used for coal transportation, the average hoisting capacity of cage/skip, hourly production capacity of coal preparation plant.

Design data are complemented by the data of the required target production of the mine, by deposit exploitation economic cryterion index and by the required period for which the mine development variant analysis should be carried out /at present the limitations of the SPP.1 package allow for analysing the variants ranging to 30 years period/.

Further more, the SPP.1 software package allows that in accordance to the requirements individual concepts may be supplemented by additional information essential for the future development of the mine [13].

Accordingly, limitations may be imposed upon the sequence of working exploitation panels and deposit if they are dictated, e.g. by surface protection conditions. Thus the data on the mine development variant required for analysis by the SPP.1 software package are the results of the creative work within the design process. Those data are called design data.

All remaining information necessary for conducting technoeconomic analyses are stored in magnetic files of the SPP.1 package and they are periodically updated on the basis of data being received directly from the computerized analytic - accounting systems for production processes and investment activities [12], [14]. They are called file data. They include such data as advance standards and price lists for headings driven under various conditions and using various techniques, as well as standard indices from safety and mine ventilation regulations, as: air quantity required in exploitation block per 1 ton of production and per one worker and admissible air velocities in various workings

Magnetic files data include also regression functions of production costs and functions of fixed assets meaning dependencies between the costs and fixed assets and the mining-technical and geologic production conditions.

In case development variant of an active mine is to be subjected to analysis by the SPP.1 package, besides the design data and the magnetic files data, the statistical data obtained in an automatic way from the data bank of the IOS [12] are also used. These data include information on actual dislocation and size of production in various mining panels, on techno-mining and geologic conditions and on actual production costs.

The above mentioned kinds of data on a mine variant create the basis for starting its analysis by SPP.1 package. The SPP.1 package conducts such an analysis utilizing the simulation method in connection with the regression prognosing method.

The block diagram of simulation-regressive analysis of mine development variant carried out by means of SPP.1 package is shown on figure 1. The main functions of basic blocks of this diagram are characterized in further points.

3. Interpretation of the accepted notations and symbols.

a_o, a_i, a_{ij} - structural parameters of the regression cost functions,

α - coefficient increasing the capital outlay needed for the primary outfit regarding the working assets and the reserves, $\alpha \geq 1$

$AT_k(m)$ - actual coal load of k-th segment of transport route from m-th deposit block,

AWE - actual output of power coal in a coal mine,

$AWEN_l(m)$ - actual air loading of l-th segment of ventilation route for m-th deposit block,

b - the year of completing the coal mine construction,

$d=b, b+1, \ldots B$ – successive years of analysis after completing the coal mine construction,

$D(v_m)$ – the range of v-th opening work performed during one month,

ΔK – increment in annual production costs in a coal mine,

Δk_j – increment of production unit costs in a coal mine,

Δn – increment coefficient of capital outlay per one ton of coal output increment in a coal mine,

ΔN – increment of capital outlay due to opening of new deposit block,

$\Delta r_1, \Delta r_2$ – increment coefficients of coal mine profitability,

$\Delta_{rq}(TB)$ – actual correction value of r-th production cost element in TB time and q-th section of technological production process calculated by means of cost regression model,

ΔU – increment of annual production value of a coal mine,

ΔW – increment of annual output of a coal mine,

Δz_j – increment of coal mine profit per unit,

ΔZ – increment of annual coal mine profit,

$i, j=1,2,\ldots n_q$ – actual coefficients of independent variables in the regression functions of the cost production model,

ICYKL – the lenght of simulation analysis cycle,

Ife – maximum number of faces included to exploitation in the exploitation panel at TB time,

$k=1,2,\ldots K_m$ – successive segments of coal transport routes from m-th deposit blocks,

$K_1(v_m)$ - unit cost of mining works during the realization of v-th work opening m-th deposit block,

K_{rq} - the value of r-th production cost element calculated for q-th section of technological production process,

K_{rq}^{s} - statistical value of r-th production cost element in q-th technological section,

$l=1,2,\ldots L_m$ - succesive segments of ventilation route for m-th deposit block,

$m=1,2,\ldots M$ - succesive deposit blocks of analysed variant of coal mine development,

$KONC_{pm}(TB)$ - output concentration from a single face in p-th exploitation panel of m-th deposit block in TB time,

M_b^q - value of gross fixed assets in q-th section of technological production process calculated by means of regression function at the time b of coal mine construction completion,

M_d^q - value of fixed assets in q-th sectio of technological production process calculated by means of regression function for d year,

MINZM - minimum change of output in the exploitation panel,

N_b - investment outlay for the primary equipping with machines and devices borne during the coal mine construction,

N_d - investment outlay for the primary equipping with machines and devices borne in d-th year after completing the construction of the coal mine,

n_q - number of independent variables occuring in the regression functions of production costs in q-th section of technological production process,

$N_1(v_m)$ - investment outlay of mining works for v-th work opening the m-th deposit block,

$N_2(v_m)$ - investment outlay for the primary equipping of the v-th work opening m-th deposit block being the heading,

$N_3(v_m)$ - investment outlay for the realization of v-th opening work being not a heading,

$OKR(v_m)$ - amortization period of v-th heading opening m-th deposit block,

$p=1,2,\ldots P_m$ - exploitation panel numbers in m-th deposit block,

$P_1\{WD(p,m)\}$ - required amount of air flowing through 1-th ventilation route segment conected with starting $WD(p,m)$ output,

$PRZYG(m)$ - duration time of first workings for starting the exploitation in the first exploitation panel of m-th deposit block,

$q=1,2,\ldots Q$ - distinguished technological sections of production process in the regression model of production costs,

$r=1,2,\ldots R$ - cost elements which are calculated by means of separate functions of regression model of costs in particular technological sections,

S - rate of interest,

$$SI(v_m) = \begin{cases} 1 & \text{- if the decision concerning the execution of v-th work opening m-th deposit block has been made} \\ 0 & \text{- otherwise} \end{cases}$$

$t=1,2,\ldots T$ - actual month of coal mine development variant analysis,

T - completion date of coal mine variant analysis,

TB - initial date of the next simulation cycle,

TK_{v_m} - completion date of v-th work realization opening m-th deposit block,

$TNW(m)$ - the earliest date of starting the exploitation in m-th deposit block,

TP_{v_m}	- starting date of realization v-th work opening m-th deposit block,
$UT_k(m)$	- capacity of k-th segment of coal transport route from m-th deposit block,
UWE	- upper limit of power coal output,
$UWEN_l(m)$	- capacity of l-th segment of ventilation route of m-th deposit block,
$UWPOZ_{pm}(TB)$	- upper output limit from exploitation level to which belong p-th field of m-th block obligatory from TB date,
$v_m=1,2,\ldots V_m$	- succesive works opening of m-th deposit block,
$WA(p,m)$	- actual output in p-th exploitation panel of m-th deposit block,
$WD(p,m)$	- additional output in p-th exploitation panel of m-th deposit block,
$WP(p,m)$	- planned output in p-th exploitation panel of m-th deposit block,
$WAPOZ_{pm}$	- actual output from exploitation level to which belongs p-th exploitation panel of m-th deposit block,
WAK	- actual output of a coal mine,
$WKP(TB)$	- planned coal mine output on TB date,
WTS	- output of a coal mine in a period preceding the date of starting the analysis of its development variant,
WYDMIN	- minimum output in exploitation panel,
$WYP_{pm}(TB)$	- maximum output of p-th exploitation panel of m-th deposit block which ensures not exceeding given exploitation advances in adjacent exploitation panels,
x_i, x_j	- independent variables in regression functions of the production cost model,
$ZAK(v_m)$	- completion date of v-th work opening m-th deposit block.

4. Preliminary calculations

After accomplishing the activities of Block 1 in which the input and control of data are performed /see fig.1/ Block 2 starts its activity. The aim of this Block is to accomplish, the so called, preliminary calculations.
These calculations include the evaluation of the preliminary values of all the coal mine parameters that are used in succesive cycles of she simulation analysis variant.
In case of active mines in this Block, on the basis of the statistical data, the actual exploitation front is reproduced - e. g. the actual output of exploitation panels is recorded, as well as, the load per transport and appropriate ventilation routes caused by this output. Also in Block 2 in case of active mine analysis preliminary correction values of production cost forecasts are appointed. They are calculated by means of regression model of production costs of SPP.1 program package.

Regression model of production costs of the SPP.1 software package covers a number of functions defining the costs borne at some specific appointed technological sections of the production process such as: exploitation panels, horizontal transportation, vertical transportation etc. [10].

The applications of separate functions for various components of production costs, such as: labour expenses, costs of materials, depreciation costs and all the remaining costs are foreseen within the technological sections. The depreciation functions do not include those related to mining workings.

Separate functions of production costs foreseen for various technologies of the production process are used in some of the technological sections. The costs, for example in a defined mining panel are calculated by means of a function adequate for the used exploitation method.
The generalized form of regression functions of production costs is presented by the formula /1/:

$$K_{rq} = a_o + \sum_{i=1}^{i=n_q} a_i x_i + \sum_{i=1}^{i=n_q} \sum_{j=1}^{j=n_q} a_{ij} x_i x_j \qquad /1/$$

The value of correction /deltas/ of production costs calculated by means of costs function being actual at the beginning of analysis is evaluated from relationship:

$$\Delta_{rq}(0) = \frac{K^s_{rq} - K_{rq}}{WKS} \qquad /2/$$

Within the technological section of"exploitation panel" the delta values are calculated for each active mining panel by means of subsituting the values of a given panel to formula /2/. The average delta values are utilized for calculating production costs in new exploitation panels.

As the elements causing occurrance of discrepancies between the calculated costs and the actual ones are not exactly known during the simulation analysis of a mine development variant, the values of deltas applied for corrections of production costs are gradually cut down in time until their full liquidation [7], [10].

Besides calculating the $\Delta_{rq}(0)$ value Block 2 realizes "time analysis" of mine technological network by means of special method developed for partially directed networks[2]. As a result of this analysis the earliest dates of opening particular deposit blocks are indicated in Block 2. In case of a planned mine construction this analysis appoints the earliest date of obtaining the first output. This date settles the beginning of the first simulation cycle of mine variant analysis-TB. The TB date of active mine is equal to the date of the beginning of variant analysis.

5. Basic cycle of simulation analysis

The cycle of simulation analysis variant starts in Block 3 in which the necessity of initiating new output is investigated. The necessity of initiating a new output is confirmed in case if inequality occurs:

$$WKP(TB) - WAK > 0 \qquad /3/$$

Investigation process of the required output starts from analysing the possibilities of increasing the output in active panels /Block 4/. Surplus values of $WD(p,m)$ output obtained in "p-th" active panel of m-th block have to satisfy simultaneously the following conditions:

$$WA(p,m) + WD(p,m) \leqslant WP(p,m) \qquad /4/$$
$$WAPOZ_{pm} + WD(p,m) \leqslant UWPOZ_{pm}(TB) \qquad /5/$$
$$WAK + WD(p,m) \leqslant WKP(TB) \qquad /6/$$
$$\bigwedge_{k \in K_m} [AT_k(m) + WD(p,m) \leqslant UT_k(m) \qquad /7/$$
$$\bigwedge_{l \in L_m} [AWEN_l(m) + P_l\{WD(p,m)\}] \leqslant UWEN_l(m) \qquad /8/$$
$$WA(p,m) + WD(p,m) \leqslant WYP_{pm}(TB) \qquad /9/$$
$$WD(p,m) \geqslant MINZM \qquad /10/$$
$$WD(p,m) \leqslant IPe \cdot KONC_{pm}(TB) \qquad /11/$$

If the panel contains power coal then additional condition is tested:

$$AWE + WD(p,m) \leqslant UWE \qquad /12/$$

If in the course of trying to increase the output in active panels the planned mine output on the TB date has not been achieved then the Block 6 starts its analysis in which the possibilities of assigning for exploatation the new panels from active and not yet opened deposit blocks are consivlered.

To indicate the not yet opened blocks which can be taken into account while analysing the increasing mine output the following condition are tested:

a/ is it possible to start the exploitation of m-th block in TB time if the development workings were started respectively in advance ?

b/ are there any designer restrictions on the sequence of exploitation of considered block ?

c/ Does starting the exploitation in this block disturb the sett-led number of simultaneously active production levels ?

The answer, which deposit blocks satisfy a/ condition can be obtained by means of performing the time analysis of technological network taking into account the earliest dates of accomplishing development workings. The time analysis includes also those mining workings of which the completion dates were earlier established in order to open some other deposit blocks. To assure the opening of a given block the date of performance of those mining workings can be changed to an earlier one.

The date of starting exploitation of the block is assigned from the relation:

$$TNW(m) = \max\left\{\left[\max_{v_m \in V_m} ZAK(v_m) + PRZYG(m)\right], TB\right\} \qquad /13/$$

Block 6 initially assigns only one exploitation panel from all deposit blocks already opened and possible to be opened on TB date, which fulfils the designing limitations in advansing exploitation of adjoining panels and at the same time assures the access during the exploitation to other deposit blocks according to the used analysis criteria - minimum unitary discounted division costs or division profit.

After determining the exploitation panels in particular blocks assigned for exploitation Block 7 starts their selection. In the first turn, permissible output in particular exploitation panels is calculated. The above mentioned conditions i.e. from /4/ to /12/ are investigated, only condition /10/ is replaced by the following relationship:

$$WD(p,m) \geqslant WYDMIN\left\{KONC_{pm}(TB)\right\} \qquad /14/$$

Panel selection for exploitation is done in such way as to optimize one, from the selected by the designer, criterion of mine variant analysis. These criteria can be:

a/ maximization of increment of coal mine profit per unit Δz_j:

$$\Delta z_j = \frac{\Delta Z}{\Delta W} = \frac{\Delta(U-K)}{\Delta W}, \text{ zł/t} \qquad /15/$$

b/ minimization of increment in production unit costs in a coal mine Δk_j:

$$\Delta k_j = \frac{\Delta K}{\Delta W}\ , \text{zł/t} \qquad /16/$$

c/ maximization of increment coefficient of profitability Δr_1 determined by formula:

$$\Delta r_1 = \frac{\Delta Z}{\Delta K} \qquad /17/$$

d/ maximization of increment coefficient of profitability Δr_2 determined by formula:

$$\Delta r_2 = \frac{\Delta Z}{\Delta N} \quad \text{when } \Delta N \neq 0 \qquad /18/$$

$$\Delta r_2 = \Delta Z, \text{ when } \Delta N = 0 \qquad /18'/$$

e/ minimization of increment coefficient of capital outlay per one ton of coal output:

$$\Delta n = \frac{\Delta N}{\Delta W}\ , \text{zł/t} \qquad /19/$$

The required increments of costs production for indices entered as formulae from /15/ to /18'/ are assigned as costs differences obtained in a mine after probationary incorporation of the considered panel into exploitation and costs before incorporating this panel. If the considered exploitation panel belongs to deposit blocks yet uncovered, then the ΔK costs difference calculated by means of regression function is increased by the sum of amortization rates of development headings. The amortization rate of each v_m development workings being a mining heading is calculated from the following relationship having regard to S interest rate:

$$A(v_m) = \frac{N_1(v_m) * \left[S * (1+S)^{OKR(v_m)}\right]}{(1+S)^{OKR(v_m)} - 1} \qquad /20/$$

while $N_1(v_m)$ investment outlay of mining works for each v_m development heading opening the m-th block, is calculated according to the formula:

$$N_1(v_m) = \left\{1-ST(v_m)\right\} \sum_{t=TP_{v_m}}^{t=TK_{v_m}} D(v_m)*K_1(v_m)*(1+S)^{TB-t} \qquad /21/$$

During the $N_1(v_m)$ outlay calculation the headings indicated as those opening the considered block but qualified for earlier exploitation to open other blocks, are ignored in this consideration / ST (v_m) index in formula /21/ has a value of 1 if the heading was earlier qualified for exploitation; otherwise this index is equal to 0/.

Investment outlay increment occuring in formulae /18/ and /19/ include $N_1(v_m)$ outlay for constructing the mining headings, as well as $N_2(v_m)$ outlay for equipping these headings, and $N_3(v_m)$ outlay for the realization of some other development workings of the considered block which are not headings. Uniform outlay consumption is assumed while calculating $N_2(v_m)$ outlay and $N_3(v_m)$ outlay during the work realization. That is why the formulae of their calculation are analogous to formula /21/. The Δ N increment of investment outlay is calculated from the relationship:

$$\Delta N = \sum_{v_m=1}^{v_m=V_m} N_1(v_m) + N_2(v_m) + N_3(v_m) \qquad /22/$$

The Δ W increments of mine output occuring in formulae /15/, /16/ and /19/ are equal to the WD(p,m) output of assigned /candidating/ panel for exploitation. The Δ Z increment of mine profit calculated for indices described by means of formulae /15/, /17/, /18/ and /18/ is equal to increment difference of ΔU mine output value which is calculated as a producet of selling price of p-th panel and its WD(p,m) output and to Δ K increment of cost production.

After analysing all assigned panels they are included into exploitation such a panel that ensures the most advantageons values of calculation criterion index. The incorporation of a panel into exploitation is accomplished by Block 8.

This block records the actual output exploitation panel and actual reserves of transportation and ventilation routes. If the incorporated panel is in the not yet opend block then time analysis of technological network is started according to the very latest possible dates. According to these dates time shedule of opening deposit block is started and the correction of volume of amortization rates calculated by means of formula /20/ for all blocks which execution dates were shifted in respect to the dates assigned for earlier block deposit is made.

When the analysis conducted in Blocks 3 to 6 indicates lack of possibilities of achieving the target mine output by means of increasing the output in active and new panels, and in the past this volume has been achieved at least in one cycle, then Block 9 examines additional possibilities of starting reserve production. Starting reserve production means the increase of output in all active exploitation panels by determined per cent which is not higher then maximum value defined on magnetic file data and which ensures the achievement of target output.

After achieving the required output in a mine or after analysing all possibilities of achieving such output, indispensable information concerning the period which starts on TB date are stored in Block 10 to represent them in results. The examination whether in the above period the date of mine analysis termination was achieved is followed in Block 11. If the termination date of the above period is smaller than the date of analysis termination, then in Block 12 the new value of current date bigger by the assumed length of cycle /ICYKL/ at the beginning of analysis equal to certain number of months 6, for example, is assigned. All mine parameters, depending on time, are set for new TB date. It can be noted that the reduction of resources in active exploitation panels together with the termination of some panels exploitation, elimination of mine reserve output, updating of reserves on transportation and ventilation routes which had been increased due to the termination some panels exploitation and values required in new TB date of additional mine output are set. For the requirements of cost model the values of Δrq (TB) and values of independent variables relating to the structure of the mine are updated. Next, Block 3 starts new simulation cycle.

6. Final calculations

After attaining the termination date of analysis Block 13 starts its work and realizes final assignment of investment outlay in a given time in tested variant of mine development.

Following parts can be distinguished in outlays concering:

- driving of development headings
- initial equipping of underground and the surface of a mine
- equipment replacement.

Outlays for headings driving are calculated in accordance with formula /21/ after eliminating in it the interest factor. The other types of outlays are calculated on the basis of designing data in technological network or in special source documents.

Upon completing the analysis of preliminary designing conception concernig the construction of new mines it is possible to utilize the regression model of forecasting the outlays assignment for the initial underground equipping or /and/ surface equipping. The regression functions of fixed assets utilized for that purpose represent dependences between the gross value of fixed assets in distinguished technological sections of production process, and the attained indices of production concentration in a mine and its structure.
The general form of fixed assets function is analogous to the form of costs model function which is described by formula /1/. In oposite to the regression cost model in the regression model of outlays assignment t ere is only one function of fixed assets concerning all active panels of a mine and representing section of "the exploitation panels". The outlay volume for the initial equipping is calculated by means of the following formulae:

I. Outlays borne during mine construction - N_b

$$N_b = \alpha \sum_{q=1}^{q=Q} M_b^q \qquad /23/$$

II. Outlays borne in consecutive "d" years after mine construction completion:

$$N_d = \alpha \sum_{q=1}^{q=Q} \max \left[\left(M_{d+1}^q - M_d^q \right) , 0 \right] \qquad /24/$$

It is assumed that the outlays bearing will last till the end of terminating the mine construction while calculating N_b investment outlay for the initial equipping utilizing the regression function. The beginning of outlays bearing for the initial equipping is established for one year before the date of obtaining the first output. For the outlays calculated in accordance with formula /24/, one year cycle of outlays bearing together with the termination at the beginning of d+1 year is assumed.

The two last Blocks 14 and 15 are used to represent analysis results of mine development variant. Block 14 formulates the basic set of 16 result sheets. These sheets contain the dynamic characteristics of production and investment activities of a mine, like production figures in consecutive years together with production distribution in deposit blocks, production costs and the flow of required investment outlays. Time schedules for execution of investment construction and for exploitation in separate mining panels are also presented.

In the result sheets the production costs, the investment outlays and the production value with a due consideration of discount account are presented for the purpose of comparisons of various alternatives for development of mines.

7. Results of the hitherto applications of the simulative-regressive prognosing method.

As already mentioned under chapter 1, the beginning of applications of the simulative-regressive method for assessment of development variants by means of the SPP.1 software package ranges back to 1972. At that time, the coal mining industry design offices have prepared data relating to the prospective development of three active mines and of one new mine project. Results of those analyses were utilized mainly for checking the correctness of solutions adopted for the program package. During 1974-1979 the method has been applied for analyses of prospective development variants for twenty two coal mines. All together for the mines over forty variants have been analysed by this method [4], [9].

Observations as to the hitherto implementations of the method indicate that the mine managements were aiming mainly at the technical assessment of correctness of various planning and design concepts for development of the mines. Development of the planned production at assumption of variants featuring considerable rate of production growth of the mines were followed with a special interest. Detecting and overcoming of "bottlenecks" in the production process or the analysis of possibilities on shortening the lead times in reaching the target productions [4] were quite frequently assumed as the task for the analyses. Comparison of economic effectiveness of the variants almost as s rule were taken for a secondary task of the analyses, considered only then, when the analysed variants were reaching the planned technical parameters in result of consecutive corrections and complementations introduced to concept desings.

A broad range testing has been conducted on the designed construction variants and on prospective development of mine in a mining ares taken as a proving ground, in order to improve the knowledge about the SPP.1 package possibilities in the above mentioned basis range of its implementations [11]. For this development area having a shape close to a rectangular of 6 x 3,6 km in size alltogether 22 development variants for the mine under desing were prepared. The variants were differing among themselves by their opening characteristics, by the strategy of reaching the target production and by the anticipated technological standard of exploitation. All the variants were analysed for an interval of twenty years. As the basic criterion an assessment of economic effectiveness for the considered variants the production costs and the capital outlays indices were assumed.

The production costs received in the analysed variants after their arrangement in acordance to the yearly production are shown on fig.2. It results thereof that for the range of a defined mining area the production costs may be very much differentiated, depending upon the solutions applied in the design. The lowest average unit cost to the level of about 250 zlotys per ton has been reached in variants No. 19 and 63 for which the production was taken as 7.200 thousand tons per year. The highest average unit cost has been reached in variant No. 17 of a production of 2.400 thousand tons per year. It was 383 zlotys per ton, so it was by 130 zlotys per ton higher from the "cheapest" variants.

Quite essential discrepancies in the analysed mine variants occurred also in capital outlays requirements for the production. Fig. 3 shows, how the capital outlays requirements index, calculated as the ratio of investment outlays born from the beginning of the analysis of investment outlays to the yearly target production capacity, was forming in time. It results there of, that the value of that index, calculated for the time of the end of analysis period in various variants was within the range of 550 to 920 zlotys per ton of the yearly target production capacity.

Results of the hitherto implementations of the SPP.1 package for simulative-regressive assessment of over forty development variants in twenty two coal mines as also of over twenty variants of a mine on an exemplary mining area indicate for efficiency of the substantial and programming solutions adopted therein. The simulative-regressive analysis of various design solutions carried out for the assumed mining area has proved that for the same mining area, thus identical deposit conditions the exploitation results of the mine might be much differentiated. This confirmed the observations from the practice. At the same time it has indicated for a much higher sensitivity of the method to the influence of design parameters of mines onto their effectiveness in comparison to the conventional analytical methods [5].

The obtained efficiency of the method allows to talk about the application possibilities of a new hard coal mines size and structure optimization method, hitherto not being applicable. The functional merit of this method lies in a broad methodic preparing of development variants for all active mines of the coal industry and as also for prospective variants of construction and development for the designed mines, then drawing an all-aspects analysis for each variant by means of simulative-regressive method and at least in selectioning of COMPARATIVE ASSESSMENTS obtained in this way for the development program of the hard coal industry [3]. In result thereof the considered mines one development variant would be advisable being optimal one from the viewpoint of criterious assumed for the coal industry as a whole /e.g. costs minimum, maximum of profits etc. at the projected global production, investment outlays limitations etc./

8. Conclusions

1. In the course of testing conducted during 1972-1979 in several coal mines the suitability of the simulative-regressive method for assessment of prospective mine development variants has been fully proved. Results of the calculations made for about forty variants of mine development, characteristized by a broad variety of ways of opening the deposit, of the designed technological standard and of geological production conditions have indicated at the same time a high efficiency of programmistic solutions implementing the simulative-regressive method of analysis. At the same time the presented basic results of the experimental testing of over twenty variants for

construction and development of mines on a given exemplary mining area have proved that the integration of the simulative determination of indices representing the technical and mining conditions of the production with the regressive models of prognosing assures a precision in assessment of influence of the mine structure and its technological standard onto the costs and capital outlays requirements of production, unattainable by the conventional analytic and design methods.
Those results confirm the purposefullness of utilization of the simulative-regressive method to the process of VARIANTS design of construction and development of mines. Therefore, it should find application in design offices as a common working aid for designers preparing concepts on prospective development of mines.

2. A continuous technological and technical progress leading towards creation of mines having higher and production capacities, as also tightening the requirements as to the quality production parameters of the mines implies the necessity of continuation of research on improving the simulative-regressive method for assessment of mine development variants towards expansion and deepening of the rangers of analyses conducted by its application. A further improvement in accuracy of assessments of mine development variants by means of the simulative-regressive method as also a diminishing of laboriousness in preparing of data for calculation would be the subject of a further integration of the method with the computerized accountance and analysis systems for production and investment processes functioning in the coal industry [4], [9].

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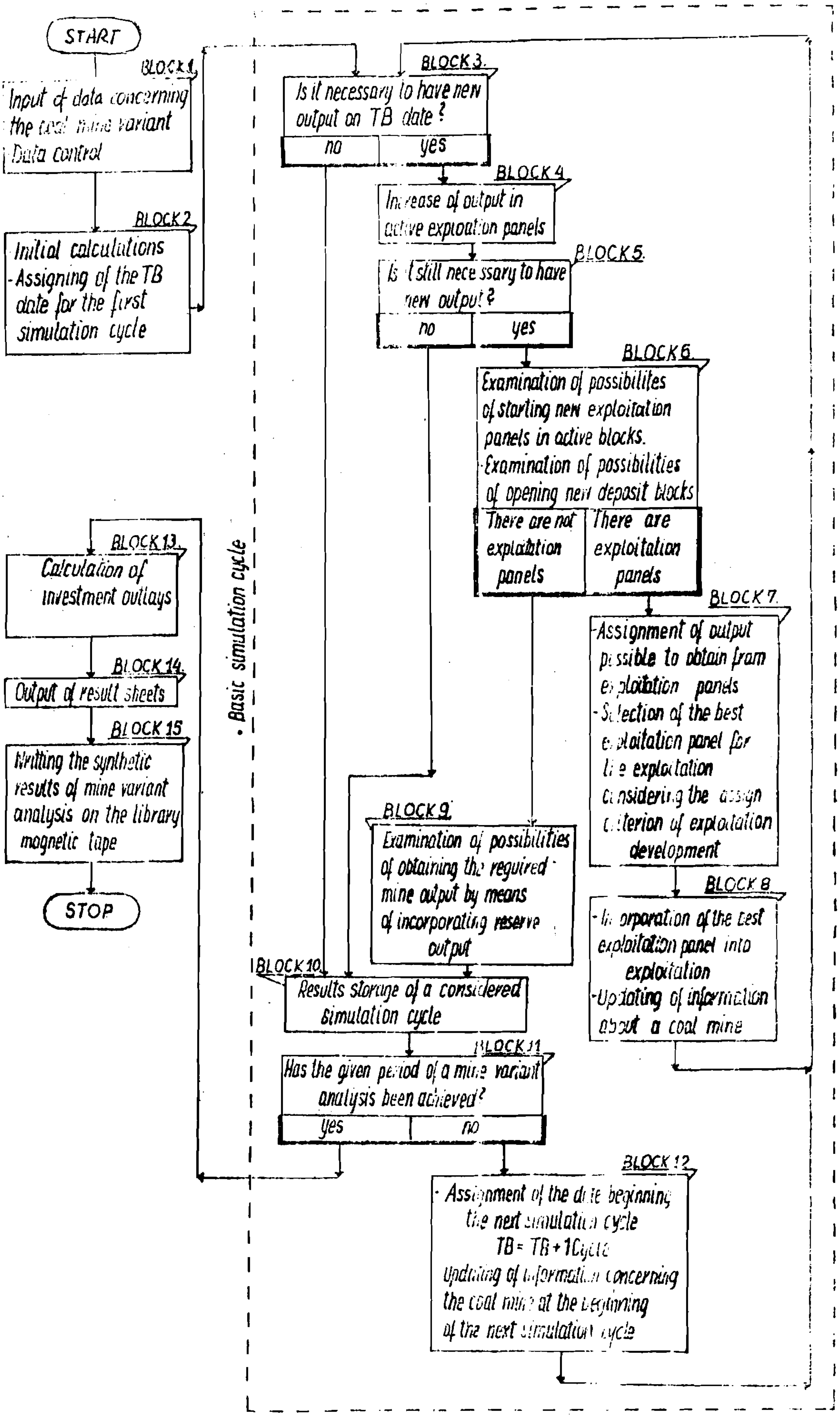

Fig.1. Block diagram of mine development variants of simulative - regressive analysis operated by means of SPP.1 program package.

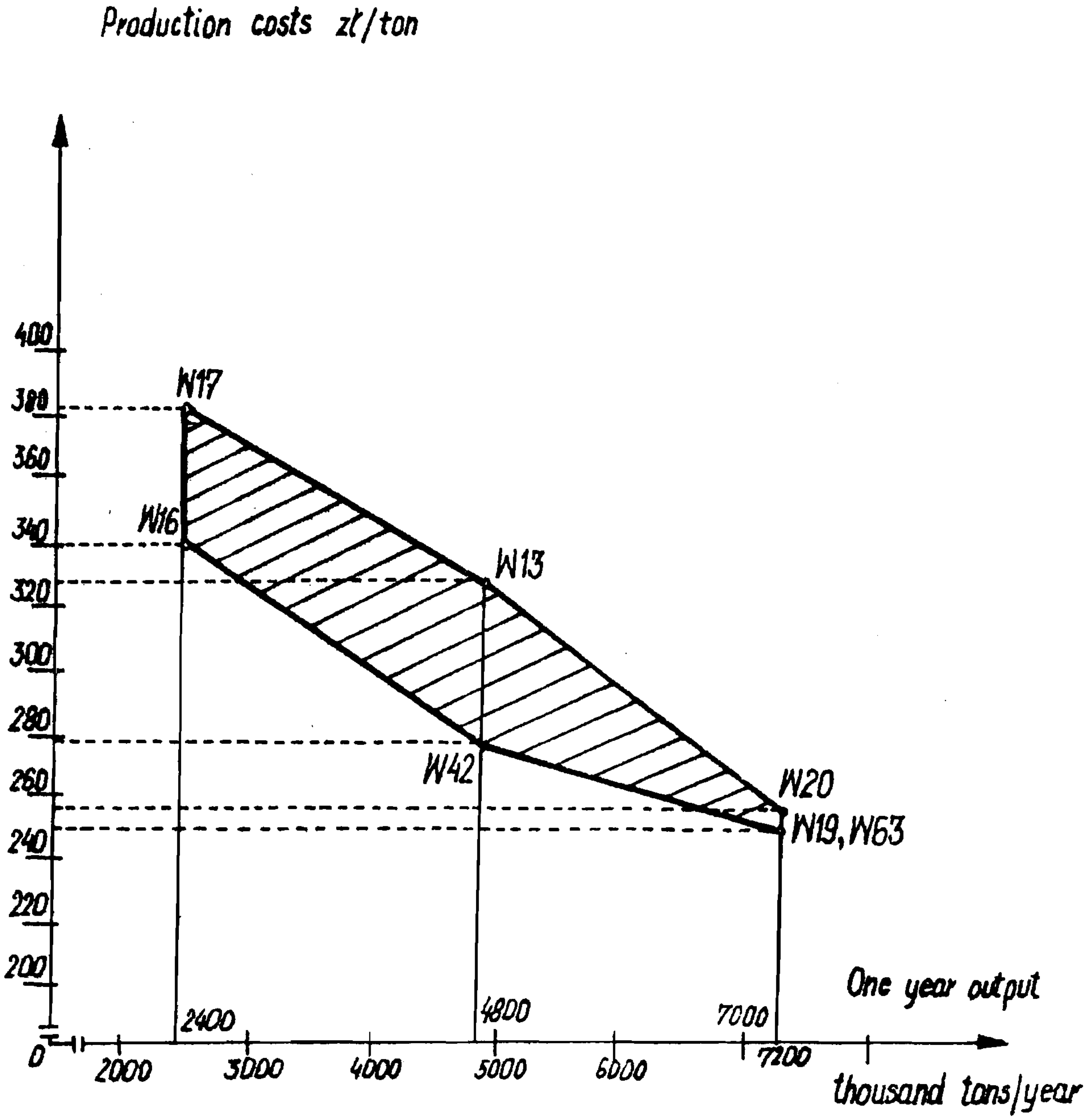

Fig.2. The range of average unit production costs obtained in analysed variants of a mine designed on defined mining area.
W 13, W 17,......, numbers of analysed variants.

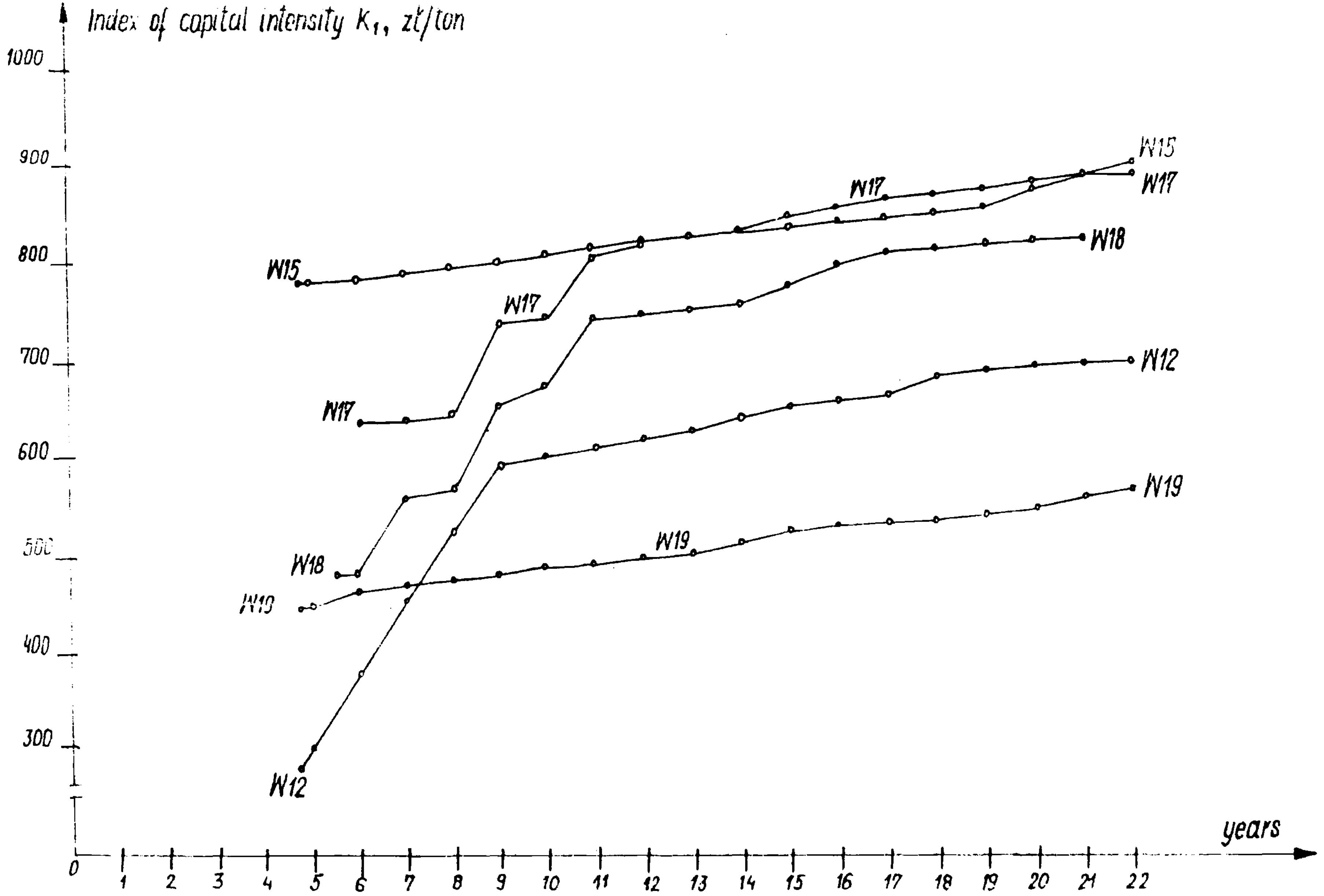

Fig.3. Capital intensity index K_1 in the chosen mine variants calculated as the ratio of investment outlays born from the beginning of mine construction and the annual target output.
W 15, W17,....., numbers of analysed variants.

COMPUTER TECHNIQUES IN PLANNING AND PROGRAMMING OF MINING PRODUCTION IN POLAND

Andrzej Jaśkowski
Wacław Szulakowski

In the Polish coal mining industry planning works are carried out within a certain cycle which is called the predicting and programming cycle. This cycle includes:

- the development forecast of basic techno-economic indices which characterize the individual coal mines and the hard coal sectors, as a whole,
- the study on conditions which determine the coal sector's development; it is the basis for decision - taking on production and investment activities.

The cyclical planning character is brought about by the necessity to revise again and again the data which are used for calculations. These data are endogenous /i.e. they appear within the sector/ and exogenous /from outside the sector/. The cycle is an integral part of the nation-wide planning system. Hence it contains the characteristic parameters of the system as well as the features of the specific subject sector for which the computer techniques are applied.

1. Planning system

The National Economic Plan is implemented by means of the whole system of disaggregated plans which include various domains of the social and economic life of the nation and are prepared for various periods.

The system comprises short-term /annual/ plans, mid-term /3-5 years/ plans and long-term /15-20 years/ plans as well as general perspectives which are prepared for more than 10-year periods.

There are some correlations between individual patterns of pland and perspectives. These correlations may be characterized as follows:

- the economic perspectives represent the multi-variant studies where the most probable future course of the examined issue is presented in the conditions of various constraints and factors which are difficult to anticipate and which affect /disturb/ the said course;
- the long-term plans which indicate the basic development problems of the sector or the national economy as a whole, including the results of the perspective studies and taking into considerations the current economic potentials in the light of the required course of the investigated issue;
- the medium-term plans prepared on the basis of the long-term plan outlines correspond strictly to the National Economic Plan and are more detailed, and the solutions included therein are adjusted to the variable external and internal conditions;

- short-term plans include problems arising from the medium-term plan, in terms of quantity, quality and lead times, these plans are obligatory and constitute the directives for the individual units responsible and accovutable for the execution of the planned objectives.

The planning system being in force in Poland may be called "the planning system with the mobile long-term plan", or "the step-wise planning system. The basic idea of this system is shown in Fig.1. The long-term plan with its production objectives is an auxiliary analytical instrument which helps to prepare medium-term plans for the coal industry's development. At the beginning of each 5-year period, a new long-term plan is prepared; in relation to the preceding plan, its values are verified /reduced or increased/ according to the conditions which result from the current general development policies of the country. In this connection, the tasks included in the medium-term plans are verified respectively and consequently, the one-year plans are also revised.

Such a meaning of the long-term plan function brings about a constant revision of this plan and obviously, the revisions of medium- and short-term plans are also needed.

Since 1976, the methodology as well as study and research works, which substantially support the planning activities of the mining industry, have been performed in the Chief Mining Study and Design Office within the framework of a separate research and development problem: "Forecasting, programming and planning of the coal mining industry's development". These works make a basis for decision-taking by management of the coal mining industry in the field of investment and production activities, so as to provide the proper development of the industry.

As has already been mentioned these works are carried on according to a certain reiterating research cycle. The research cycle can be described as follows. The starting point or these works are the available production capacities at this moment, and the data which identify the investment activities of the coal mining industry and the size of hard coal demand for the country's economy.

The first stage of a cycle includes multi-variant perspectives of the individual coal mines and of the whole coal mining sector.

The second stage is the identification of conditions which restrain the sector's development; the conditions are the consequence of a certain selection field; within its frames, the most probable development trend of the sector will appear. The worked out techno-ekonomic indices indicate the minimum and maximum potential of the coal mining industry's development /within the investigated time interval/.

Within the third stage, optimized programs are prepared which fulfil the condition of meeting the coal demand and other conditions which result from the assumed criterion-function and the remaining limitations. These programs also include the existing technical and economic constraints of the coal mining industry as well as the market analysis carried out by respective institutions. Within the final stage of the cycle, i.e. on the sector management level, decision taking actions are carried out with reference to the production objectives and indispensable investments, so as to warrant the attainment of the required size of production. At each moment of the cycle implementation, data are introduced into the forecasting and programming works. The data update the identyfication degree of the resources base and its qualitative parameters.

At present, the major part of calculations carried out at the successive stages of the whole forecasting programming cycle implementation is included in the respective saftware, and is performed by means of digital computing techniques.

Recently for forecasting purposes, and particularly to optimize the coal mining industry's development programs, a certain group of methods has been used sucessfully called MOBAR.

It has been worked out at the Institute of Designing and Construction of Mines of the Academy of Mining and Metallurgy in Cracow.

2. Characteristics of the MOBAR method

The MOBAR metod incorporates all stages of the above described cycle: from forecasting the techno-economic indices for mines to preparing the coal mining industry's optimized programs.

To this end a software package for calculations has been worked out. The programs - according to requirements - may be utilized separately, in groups /for the selected cycle fragment/ or on the whole /for the whole cycle/.

The basic requirement of the method consists in the general collection of designs for the existing mines, mines under construction, and planned mines.

The collection embraces variants of these mines development within a period equal to the programming period. This period included the years 1975-2000 in the already executed works. Each variant has been characterized by a sequence of numbers of techno-economic indices such as: coal mine output, the share of steam coal in the total colliery output, production costs, depreciation, forecasted coal sale price, capital expenditure for the output maintenance and for the output increase, capital expenditure per one ton of coal production, labour productivity etc. The indices present univocally the expenditures and the results which are connected with the implementation of each mine-variant. The number of the numerical sequence terms of each mentioned index equals to the number of the years included in the program. To indicate each micro-economic index, different methods of forecasting its value were used. However, most frequently a modified trend - extrapolation method or methods of the principal indices were used according to the substantial content of the index. For each mine, at least two development variants: minimum and maximum, have been prepared.

Besides, the intermediate variants /third and fourth ones/ for the existing mines which have sufficient reserves to increase the initial coal output and for the planned mines have been elaborated.

The said variants were justified from the viewpoint of the opening up and development of the coal deposit /number of shafts and working horizons, the degrea of the production processes mechanization, the amount of coal output, etc./

By means of relevant calculations, a catalogue of technical and economic indices has been prepared, which includes indices of the mines development variants. On the basis of the describad variants of the individual mines development, it was possible to start working out the projections relating to the macro-economic indices of the sector's development. This was done through synthetizing the macro-economic indices for different sets of mines aggregation.

There were aggregated separately:

- the existing mines
- the mines under construction, and
- the planned mines.

For each of the above mine groups, the average technical and economic indices were calculated according to their variants with

- minimum coal output
- maximum coal output

Subsequently, the indices were computed for the mines producing

- steam coal and
- coking coal.

Furthermore, a forecast was worked out of the development of the above said indices in conditions of variable rates of including new mines into the coal industry's development program. It was assumed that these mines will be constructed at following rates:

- one mine ~~wery~~ every two years,
- one mine per annum,
- two mines per annum.

Finally, the indices were calculated for various combinations of the mentioned groupings of mines and of the capital investment rate in the coal industry.

As a result of the above activities, the extreme potential of this industry's development was determined, and particularly with reference to the amount of coal output and the respective output indices. This fragment of the computing cycle produces the most appropriate forecasting of the coal mining sector's development in a macro-economic scale, and has become the basis for the determination of limiting conditions in the assumed model of optimizing the development program - of the coal mining sector.

In the two first stages of the forecasting and programming works, the necessary numerical data set has been prepared. The data are finally used in the optimization program for the sector's development. These data are supplemented with figures derived from outside of the sector and are characterized by:

- home demand for steam and coking coal
- commitment of the capital investments allotted from the central budget;
- manpower potential within the sector, etc.

As the theoretical foundations of the optimization program for the sector's development have already been published only its short characteristics is presented herein

At the first stage of the optimization calculations, the three-dimentional matrix od mines designs /mines variants/ which create a n-element general set of these designs is prepared.

This set arrangement is carried out by the criterion - adequate for the assumed function - of the expenditures or profitability index. Expenditures are always minimized and proceeds are maximized. From this matrix, by means of dynamic programming beginning with the last year of the program period, such sub-set of mines-variants is selected in the succesive years of this period that is an optimum solution from the view-point of the assumed criterizon of "goodness" in the program's economic assessment.

The dynamic programming operator has a form of a formula enabling to calculate the weighed average of expenditures occuring in the criterion-function or of effects associated with the given mine-variants implementation. The use of such an operator allows to compare and select the best mine design, at first within the variant group /several development variants of the same mine/ and subsequently, among adjacent mines arranged in a matrix.

The mines are included in the optimum program until the moment of meeting the hard coal demand.

If commitments of the investment capital or manpower sources are the superior limitation, the optimization calculus is carried on until the investment capital or manpower sources run out. In this case, besides the accruring output volume of collieries which are included in the optimum program, there is printed the cumulative build-up of capital expenditures or men-shifts which are related to the development of these mines.

The present method enables to carry out optimization in various arrangements of mines, with the use of various optimization criteria and limitations of the various target functions as well as requirement variants.
After algorithms and software /in FORTRAN/ had been prepared, the initial calculation were carried out by means of a Honywell 3200 computer and subsequently, an Odra 1305 computer. The block diagram showing these calculations is presented in Figure 2.

3. Operative results of the MOBAR method application

Besides individual forecasts regarding the development of mines and the coal mining sector which themselves are elaborations that find practicaly use for various planning and analytical works in the mining industry, the worked out optimized programs for the coal mining industry were a substantial additional achievement of the applied MOBAR method.
The optimization calculations were carried out, assuming:

- three different optimization criteria, i.e.: minimum production cost /without depreciation/, minimum unit capital cost and maximum labour productivity,
- three different coal demand variants where one official /from the Ministra of Mining variant of the coal industry capacity development by the year 2000 was included;
- a separate optimization program for coking coal and steam coal output capacity development.

As a result of calculations, 18 various optimization programs for coal industry development were obtained. The calculations results were supported by means of a Gantt chart.

Each program has been described by a complete set of indices which are optimal ones from the viewpoint of the optimum criterion. They enable to make a mutual comparison of the programs, and finally, to select the best one.
The indices which characterize the optimized programs may be divided into two groups:

<u>A group of indices which characterize the mine-variants:</u>

- a most effective variant of development of a mine /from the viewpoint of the whole sector/ and its lead time
- the year of finishing exploitation in the existing mines that have shortly depleting coal reserves or lower - in comparison with other mines - profitability of coal production
- number, sequence and the year of beginning the construction of coal mines located on the perspective areas;
- the years of attaining initial coal output and planned production capacity.

<u>A group of indices which characterize the coal Sector:</u>

- total coal output of mines which take part in the optimized program;
- surplus or deficit of total coal output in relation to the coal demand variant;
- the optimized, ~~unit cost~~ /without depreciation/ of coal production ~~the optimized~~-the unit capital cost /per one ton of coal output/ and labour productivity;
- global capital expenditures of the coal mining sector;
- the average unit cost of coal production,
- the average selling price predicted on the basis of the coal production cost.

The limited range of this paper does not allow to discuss all results of calculations, thus only these results have been presented here which are directly related to the applied optimization criteria for steam coal. The results could be introduced in a special table. The could be built in the following arrangement: the demand variant, the optimization criterion, numerical value of the index which acts as an optimization criterion gives good opportunities for results analysis.

The most advantageous indices in individual programs have been marked with a continuous border, and the worse indices - with a dotted border.

The analysis of the data, created in the table, confirms, first of all, the rightfulness of assumptions and the correctness of calculations carried out by the MOBAR method; for, in eight out of nine cases, which were taken into account, the lowest /in the minimum function/ or the highest /in the maximum function/ values of indices were obtained in those programs where the designation of an index was compatible with the designation of the optimization criterion.

In other words the most favourable values of indices are found eight times on the diagonal line in the table.

Moreover, the discussed table shows that:

- the most favourable set of three indices - irrespective of the demand variant - was obtained when the minimum coal production cost was used as a criterion, whereby in the maximum demand variant, the program which is prepared with respect to this criterion is very strong;
- in the criterion of minimum capital expenditure per 1 ton of coal, the obtained indices set is the least advantegous

one; for in each case, ~~case~~ the remainder two not optimized indices are the highest/production costs/ or the lowest /labour productivity/

- the optimization results are most evident when the criterion of minimum capital expenditure per 1 ton of coal is applied; reduction of capital expenditure in the optimized programs with respect to this criterion are of an order of several or more billion zlotys in the particular 5-year intervals of the program's period.

On the basis of the set of three quantities considered in the course of optimization /production costs without depreciation - unit capital cost, labour productivity/, a program may be identified which should be promoted for decision-taking on the further coal output growth. This program has been marked in table 1 with a continuous border.

Summing up the above considerations, it has to be emphasized that the results achieved by the MOBAR method are a very helpful data set dor the coal mining industry. On the basis of these data the main trends of this sector's development for the 5-year period 1981-1985 and for the years ahead have been worked out. Multicriterion and multi-variant optimization has enabled to throw light from various sides upon the subject problem, has provided wide opportunities making choice by a person responsible for decision taking and has provided conditions for a deepended analysis /particularly - economic analysis/, its final purpose being the elaboration of mose advantageous programs for the development of the hard coal industry within a long time interval.

FIGURES

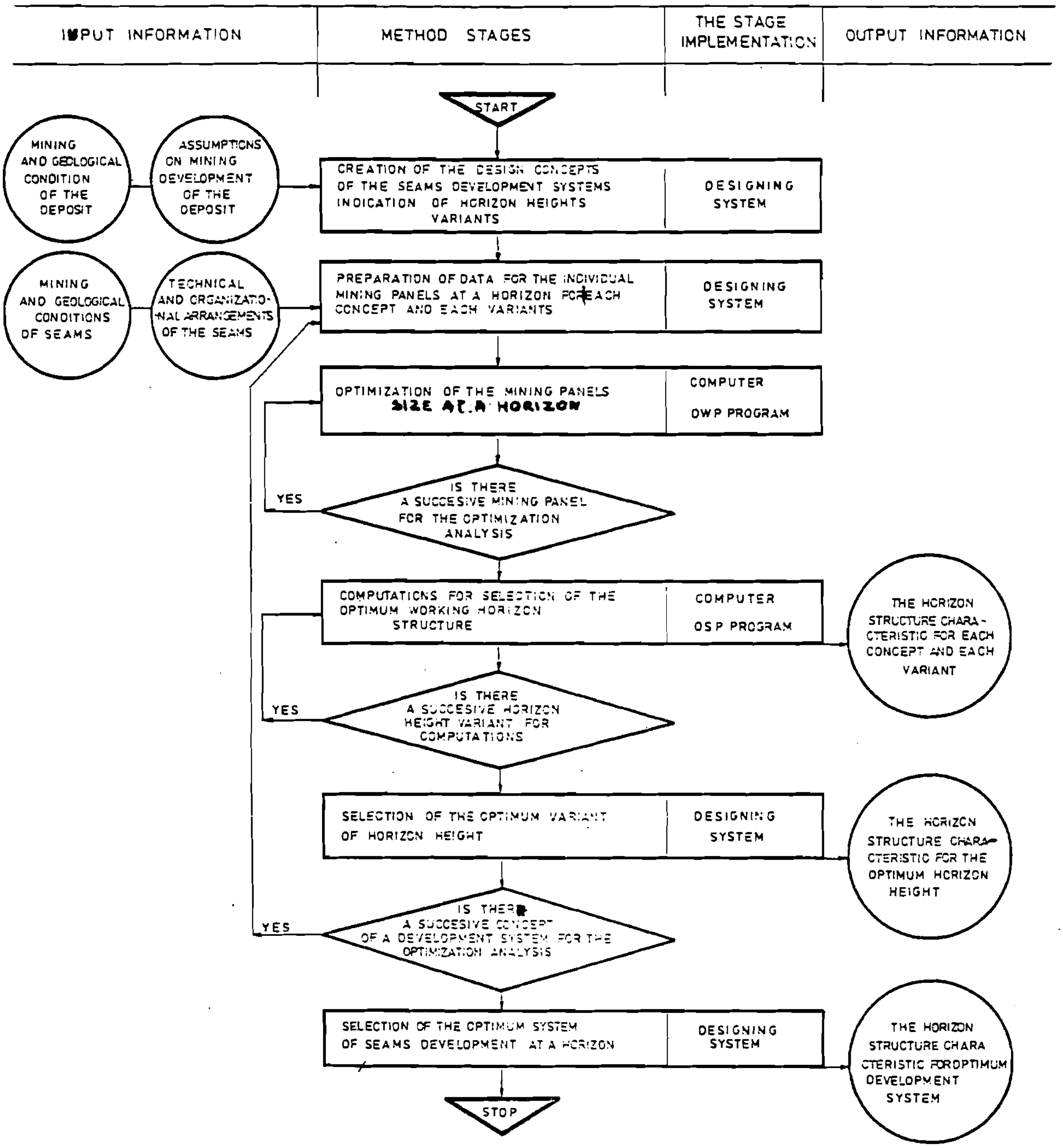

Figure 1. Model of the Planning System with the Mobile Long-term Plan for the Coal Mining Industry

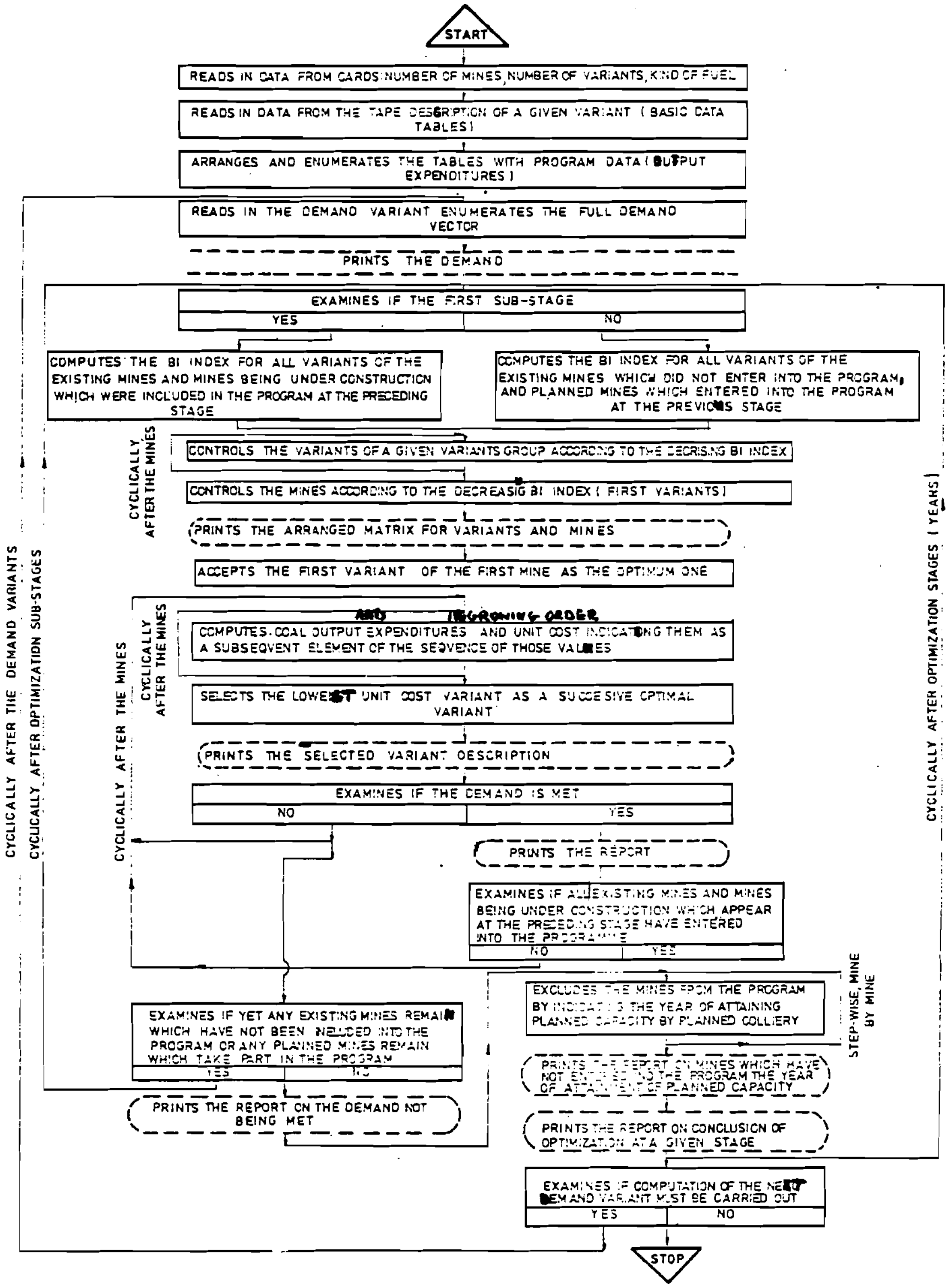

Figure 2. BLOCK DIAGRAM SHOWING THE DEVELOPMENT OPTIMIZATION OF THE COAL MINING INDUSTRY

EXPLORATION AND RESERVES ASSESSMENT IN THE UK: THE OR CONTRIBUTION

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This paper has been prepared for the meeting of the "Planning for Planning" Task Force Meeting to be held at the International Institute for Applied Systems Analysis, 24 - 27th November 1980. It is intended as a discussion paper to introduce the Reserves Assessment session, and as such has three purposes:-

(i) to review O.R. approaches currently used in this area in the U.K.

(ii) to indicate problems and problem areas encountered in such work

(iii) to provide a framework for ensuing discussion on the day.

The text of any final published paper may change in the light of such discussions.

The first section of the paper briefly reviews current U.K. exploration philosophy as practised by Geology Branch of the National Coal Board. The second introduces a broad framework for analysing possible O.R. contributions. Following sections give brief case studies of O.R. projects worked in the last few years, placing them within the framework established. The last summary section reviews this O.R. contribution, indicating those areas where problems are still unsolved.

Any views expressed are those of the author and not necessarily those of the National Coal Board.

1. U.K. EXPLORATION AND RESERVES ASSESSMENT

Current U.K. exploration philosophy, described in (1), divides exploration and reserves assessment for prospective new capacity into four phases:

Phase I	Is there any workable coal? This is answered by one borehole, which if positive gives an indication of cost of access, depth and reserves density in the target seams. From this can be derived an indication of the minimum area of such reserves needed to justify access.
Phase II	Is the newly discovered coal bearing area sufficiently extensive? A few boreholes are sited at the limits of the mining area necessary to give sufficient bulk reserves for mine viability.
Phase III	Are the target seams sufficiently undisturbed to give the required levels of productivity? The exploration requirement here is infilling boreholes and seismic lines on a ¾ to 1½ mile grid, implying 15 to 25 boreholes in a prospective take. If the answer is yes, initial selection of access site and preliminary layout evaluation are possible.
Phase IV	What constitutes "enough" in detailed exploration to support a mine plan to justify the capital required for the new sinking? The requirement here is that quantity, type and disposition of exploration which, together with the cost of insurance for lack of information, and the cost of meeting the remaining expected but unlocated disturbances makes the first ten to fifteen years of planned production cheapest to mine.

A fifth phase comprises the "exploratory content of development work in the mine once sunk" (2). This can vary in form from the implied exploration content in development through to the explicit underground exploration of in-seam seismology, long-hole drilling etc. The importance of this exploration phase must not be forgotten. In all phases except the first, information is obtained about the nature of the coal seam at a number of points. From this information, inferences have to be drawn about the properties of the seam over the whole area of interest.

2. THE O.R. PROBLEM - A BROAD FRAMEWORK

The problem in analysing exploration within the context of the mining activity has been suggested in the description of Phases III to V above. Overall, the objective is to minimise, over the life of the workings, the sum of

(i) the costs of exploration

(ii) the costs of the spare capacity installed to cater for geological uncertainty.

(iii) the operating costs that will be associated with geological disturbance in eventual workings.

Increased expenditure in the second area will reduce costs in the third. Increased expenditure in the first area may reduce costs in both the second and third areas. The determination of the correct balance between the three areas of cost is a tremendously complex problem. Even to establish a framework is difficult given the rapid changes in exploration techniques and mining methods. However, in the U.K. there has been considerable success in tackling sub-problems of the overall minimisation, so that now at least a broad categorisation of problem area can be attempted.

For exploration and reserves assessment, two distinct questions can be identified:

- What is the current knowledge from the current quantity of exploration, and by how much would knowledge be increased by given extra exploration?

- What would be the value of the extra knowledge in terms of reducing current or future costs in areas (ii) and (iii) above.

The first question can be asked for each type of exploration, for each property of the coal measures on which that type of exploration is likely to provide information. The second question can be asked for each relevant seam property. Only when these questions are answered can problems of design of exploration be tackled, in terms of either quantity, type or disposition.

A full treatment of the properties of the coal measures of interest can be found in, for example, reference (3). For our purposes here, we must at least divide the properties into two classes:

- those properties of the coal measures which are continuous:- e.g. thickness, ash, calorific value, sulphur content, chlorine content.

- those phenomena which are in their nature discontinuities in the coal measures:- e.g. faults, washouts, areas of weak roof.

The above gives rise to four distinct regions of problem, denoted in the Table below. The rest of this paper containes examples of O.R. work in exploration and reserves assessment, each case study being classified in one (or possibly more) of these regions.

	CONTINUOUS PROPERTIES	DISCONTINUITIES
Estimating current knowledge; or the increase in knowledge associated with increased exploration	α	β
Estimating the value of the knowledge in reducing the costs of mining	γ	δ

3. ESTIMATION OF CONTINUOUS PROPERTIES GEOSTATISTICS α

Samples of geological variables such as the thickness of the coal seam cannot necessarily be regarded as independent, and the probability model used must be one which includes spatial correlations. Geostatistical methods, reputedly so successful in the analysis of continuous ore deposits, have been suggested as being appropriate to coal deposits.

In the U.K. there have been several attempts to apply geostatistical approaches to borehole data. Two separate analyses have been performed on new mine borehole information, the first involving less than twenty boreholes, the second (4) approximately forty. A third exercise studied a large number of measurements of seam thickness at an existing colliery. Thus the first two analyses used data from phases II to IV of exploration, while the third concerned data from phase V.

The investigations have thrown up a number of objections to the use of geostatistics in U.K. coal exploration.

(a) The paucity of data in phases II to IV makes the estimation of the semivariograms unreliable. The data from one of the new mines did not fit the theoretical model well; the parameters estimated from 14 boreholes changed radically when information from 4 more boreholes was included. It has been asserted that about 50 boreholes are needed for adequate estimation, a number unlikely to be reached in phases I to IV.

(b) The spatial behaviour of the new mine data can generally be described adequately (for the purposes in hand) by much simpler models involving, at worst, polynomial regression, or alternatively the methods described in Section 5 below. The extra complication and computing requirements of the geostatistical approach are not justified.

(c) The semivariograms plotted for the existing colliery showed very marked anisotropy. The transformation required to render such data isotropic is a source of inaccuracy, and its intuitive significance is not clear.

This feature of the existing colliery data carries a further implication. The fact that semivariograms can vary significantly within the confines of a single pit means that great caution would be needed in assuming the form of the semivariogram at one part of a coalfield to be the same as at another. The possibili of augmenting the information about the semivariogram contained in phase I - IV data by taking account of its behaviour elsewhere should be approached with care.

$\propto$, (γ)

4. ESTIMATION OF CONTINUOUS PROPERTIES, THE LOCATION OF THE NEXT BOREHOLES IN A CASE WITH A LOWER BOUND ON THICKNESS

The foregoing section has shown that the methods of geostatistics, insofar as they are concerned with kriging are unlikely to find much application in coal exploration in the U.K. This is not to say, however, that the modelling technique on which the methods are based may not be useful. One particular study (5) has indicated lines along which such a model could be used to help in deciding on the distribution of boreholes in phases II and III exploration of a particular coalfield.

The problem was that the seams in the particular coal measures concerned were extremely variable in thickness, such variation including the minimum thickness regarded as feasible for extraction. Thus more than usual, one of the most important exploration objectives was to ensure that the seams were sufficiently thick, throughout the area marked out for possible development, to ensure feasibility. Geologists felt that seams of a nearby coalfield, for which extensive data were available, were likely to be similar in behaviour to those in question. Analysis of data from the nearby coalfield led to the conclusion that the semivariogram of seam thickness there could be adequately described by a linear model.

It was agreed with the geologists that a suitable borehole strategy would be to sink a few holes, widely spaced, to check that the behaviour of seam thickness in the prospect did indeed correspond to that in the neighbouring coalfield. After that, points where there was the greatest risk of the seam becoming too thin were identified, using a model in which seam thickness along the line between two boreholes is a Brownian motion, in order to determine the strategy for further exploration.

Thus, in specific instances where there is a risk of a particular property exceeding a limit which may affect the viability of the prospect, a strong O.R. contribution can be anticipated, both in assessing the risk that can be attached to estimates from given exploration, and to assisting in the design of further exploration. Analogous problems would be situations where, for example, chlorine or sulphur content are approaching an upper bound of acceptability.

5. ESTIMATION OF CONTINUOUS PROPERTIES ∝

GEOPLAN - A Computer system for reserves assessment

Whatever method is used to estimate seam behaviour, there remains the question of how best to organise the data so as to assist efficiently in the early stages of mine planning. The complete behaviour of target seams is best described by the geologist's isopachyte maps, and it is an essential part of their task to update these as new information and interpretations arise. However, the length of time required to produce isopachyte maps causes problems whenever it is necessary to consider a range of different mining assumptions, especially if the seam behaviour is complex. The maps are in any case not always the most convenient form in which to present information. These two reasons mean that large amounts of the geologist's time may be taken up in translating isopachyte information into reserves and/or output estimates.

To overcome the above problems, the Operational Research Executive and Mining Department have developed a computer system, GEOPLAN, to assist the communication of information between geologists and new mine planners.

For each borehole in each target seam, the thickness and ash content by weight of each individual coal and dirt parting is input to the system. In applicationswhere adjacent seams are sufficiently close that they may well be mined in a single joint section, the thickness of the inter-seam parting is also input. The geologist may 'amend' the borehole log on input to, for example, amalgamate a series of very small partitions into one combined record.

The borehole entry for each seam is condensed in GEOPLAN to a record of total coal section, total dirt section, average ash%, and chlorine%, if relevant. This information is interpolated to the centres of a square grid superimposed over the prospect (usually a 1 km^2 grid is employed). The value estimated for each seam for each grid-point is the weighted average of the records from the three nearest boreholes in that seam. Weighting factors are proportional to the inverse square of the distance between the grid point and the boreholes (ISD averaging). Chlorine interpolations take into account any known correlations with depth.

The borehole information on qualities is reflected in the grid-square ash maps, but the information on the location of the in-seam dirt bands is lost. In certain applications this may be important if there is a possibility of working reduced but significantly cleaner sections. In such cases the problem is overcome by interpolating for a series of possible sections, for example from 1m. to 3m. in steps of 25 cms, and retaining dirt and ash information for each possible section.

Before the geologist makes any use of the GEOPLAN data base, the maps are validated by comparison with his latest interpretation. Some aspects of seam behaviour are not well represented by ISD averaging ; seam splits for example require more precise treatment. The geologist corrects the data base to his own interpretation by specifying dummy boreholes in key locations which will influence interpolations in all nearby squares. As the planning process continues, and interpretations change, the GEOPLAN data base is continually updated as necessary.

The strength of Geoplan lies in the ease with which the data base can be used to provide revised estimates of reserves as mining assumptions change, as they are bound to do many times in the early stages of prospect planning. Such use has a direct impact on the vital choice of access sites. References (6) and (7) give some examples of the intensive application of Geoplan in the planning of one particular prospect, both in reserves and mine layout evaluation. The primary justification of the actual method of interpolation, ISD averaging, is that in all applications to date geologists have been readily satisfied with the seam interpretations produced, without recourse to significant numbers of dummy boreholes. A fuller comparison of ISD with other possible methods can be found in (4).

6. EVALUATING THE EFFECT OF DISCONTINUOUS PROPERTIES ON FUTURE WORKINGS: GEOSIMPLAN

8

The Operational Research Executive and Geology Branch have developed an operational gaming method to aid in choosing between strategies at any colliery, in the light of geological uncertainty. The method, Geosimplan described in detail in for example (8), has been used in the planning of some 50 collieries.

Alternative possible strategies for the colliery are determined in advance by the colliery management, and tested against alternative geological configurations, "geologies", which have been provided by the colliery geologist. Each geology is a possible configuration that is consistent with such proved information as exists, and contains projections of unknown hazards which are consistent with observed distribution (frequency, size and orientation) in nearby workings.

At the start of the exercise the planner is informed only of those parts of the geology, such as major faults, which are known beforehand. He then states the initial strategy to be evaluated, specifying resources and their development, performance levels, and a skeleton layout design. The working of the scheme is simulated by hand against one of the conjectural geological maps over a period covering 5 to 10 years of operations. The position of hazards is not revealed to the planner until they are found by faces or roadways, whereupon he must decide the future of the affected unit and, if necessary, redeploy resources and modify the layout. In this way the flow of information and sequence of decisions is as it would be in real life.

The final outcome is assessed in terms of key factors, commonly the level of production and its variability, the required development in terms of yardage, and the level of resources necessary to execute the plan. Each strategy can be tested in this way against a number of conjectural geologies until the planner develops an understanding of whether the plan is sufficiently robust to withstand the likely geological risks.

Geosimplan does not necessarily find an optimal strategy but it does permit decisions to be made on the basis of considerable synthetic operating experience. For the planner it provides a broad layout for working, suggests resource requirements and their deployment, and identifies key activities crucial to the mine's development. In addition, as with other gaming exercises, the approach has a learning value for the participants. The principal advantages of the approach are first, the realistic way in which it reproduces the flow of geological information and the sequence of operating decisions at the mine, and second, the flexibility of the technique which makes it so adaptable to the peculiarities of individual mines.

7. THE BENEFITS OF SURFACE SEISMOLOGY

δ, (β)

In the early 1970's the National Coal Board successfully adapted surface reflection seismic techniques to the special problems of identifying faults in coal measures. By 1976 it was possible to identify faults of 5m. throw under perfect seismic conditions. The problem became one of identifying those collieries and prospects where the method should be applied. A seismic survey could, at a cost, give information on the fault pattern that would be encountered in future underground workings. In what circumstances was the information worth the expenditure?

The problem was tackled using the Geosimplan approach described in the previous section. Again, the geologist prepared a number of alternative geologies; and the potential results of a 'seismic survey' of each geology were assembled. The colliery planner then prepared a number of mining strategies for the colliery.

One strategy was the best current strategy, where no additional geological information was available and the planner based his expectation on the most likely interpretation to date. The other strategies were then individually developed for each of the alternative geologies and were based on the knowledge that a seismic survey might yield.

The best current strategy was run against all the radically different geologies; the other strategies were run against their respective geologies. Two distinct strategies were therefore developed for each geology. In every case, those runs with some "advance knowledge" - given by the simulated seismic survey - gave better results than those with no advance knowledge. The financial advantage of the seismic information was then calculated and the cost of the survey taken into account to give an assessment of the return on the expenditure.

A full description of an exercise at one particular colliery is given in (9). One useful spin-off of that exercise was that the information gained from the hand simulations as to the most critical areas where major faulting might seriously affect the mine plans. This information was used in the design of the lattice pattern of the seismic grid.

8. THE BENEFITS OF IN-SEAM SEISMOLOGY

δ (β)

A very recent example where OR methods are beginning to make a strong contribution is that of the evaluation of the emerging exploration technique of in-seam seismology. By definition, such exploration is concerned with phase V, when workings are under way; but is nevertheless of relevance even in the <u>planning</u> of new capacity in the sense that reserves assessments should take into account the effect that the technology will have on future workings.

A series of such case studies are being performed to build up an understanding of how the expected benefits of in-seam seimic will vary in different conditions. This could be used in several ways.

(a) To estimate the likely national requirement.

(b) To provide guidelines for assessing individual potential applications quickly.

(c) To throw light on the operating characteristics which should be emphasised in the continuing development of the technology.

9. ESTIMATING RECOVERABLE RESERVES FROM IN-SITU COAL

$\alpha, \beta, \gamma, \delta$

This vital question has been deliberately left till last since it cannot be tackled without consideration of all the problems discussed in previous sections. The mechanism by which O.R. has contributed in the U.K. to this question is at thefirst level through the development of the Geoplan system described in Section 5. The Table below shows a possible Geoplan summary of the total recoverable reserves contained within each square and each seam, under a particular set of assumptions.

	m. Tonnes
Coal in place	C_1
Losses in boundaries	L_1
For known geology	L_2
Inaccessible sections (too close to main extraction)	L_3
Surface support pillars (explicit)	L_4
Layout support pillars	L_5
Minimum section cut-off	L_6
Quality cut-off	L_7
Roof coal	L_8
Floor coal	L_9
Additional floor coal (due to limits on maximum extraction)	L_{10}
Inaccessible areas	L_{11}
Geological/operational losses	L_{12}
Recoverable reserves	$C_2 = C_1 - \sum L$
Estimated % extraction	C_2/C_1

Thus a series of deductions in either working section or plan area of working are made to the coal in place estimate. From the point of view of the final recoverable reserves estimate, the ordering of the deductions is a matter of presentation only. (For other more specific questions, it becomes essential to choose an order appropriate to the question). The final calculation of recoverable reserves requires a conversion factor to convert to equivalent saleable, and this requires a knowledge of the quality of the precise coal being considered after all the deductions have been made.

At a second level there is a deeper O.R. contribution. The case studies that have been described, together with other continuing O.R. work not covered in this paper, all contribute to the understanding of what deductions should be applied in each loss category. Further, they contribute to the vital question of how those deductions might change in the light of economic considerations, changes in mining technology, and changes in the technology of exploration itself.

10. SUMMARY OF PROBLEMS AND PROBLEM AREAS

This paper has shown how the balance of U.K. OR work in reserves assessment is heavily influenced by N.C.B. management needs, which are themselves partly governed by the nature of the coal seams themselves. This has meant a high level of successful effort on problems concerned with how discontinuous seam properties are likely to affect future workings, and how beneficial increased knowledge is likely to be. On the other hand, with the exception of one single surface seismic study the O.R. contribution into how such knowledge is gained has been limited to the statistical analysis of worked areas; the development of surface seismic techniques and the design of seismic grids has been perceived as a geotechnical problem.

Some contribution might be made, however, to the technical development of in-seam seismic, in that O.R. work may indicate the technical goals which are most worthwhile.

With borehole exploration, typical U.K. borehole density has militated against sophisticated estimation of continuous seam properties. Only in the case outlined in section 4 has there been a significant contribution to exploration design. In most prospects, once phase II -III exploration is successful, emphasis switches away from reducing the uncertainty of seam thickness estimates, again reflecting the concern with seam disturbances. In any case, it is difficult to determine how reducing such uncertainty can be reflected in reduced costs. Thus, we have no analytical approach to analyse the question of why the borehole density is at the level it is, and why it is different in other countries. We have no established analysis framework if asked where the next borehole should be sunk in a partially explored prospect.

Nevertheless, the O.R. contribution to reserves assessment in recent years is strong, in particular in the key area of providing models which will link the work of the separate specialisms of Geology and Mining Engineers. Emphasis has been placed on uncertainties of mining technologies and mining alternatives in the given seams, and how these uncertainties affect reserves assessment. We believe that, even with a relatively sparse borehole density, analysis of these uncertainties is the most crucial in determining the key decisions of size of mine and choice of access.

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PLANNING FOR PLANNING TASK FORCE MEETING OR AND SA IN NEW CAPACITY PLANNING

THE EFFECT OF INTERRELATIONS AND UNCERTAINTY ON THE MINING STRATEGY

M.W. Hancock

1. General Comments

In a problem area as wide-ranging as new capacity planning it is inevitable that the total problem area should be broken down into a number of smaller problem areas, or sub-problems, in order that each of these can be more fully examined. These sub-problems might be exploration, the assessment of reserves, layout assessment, manpower planning, coal preparation and marketing, surface facilities and transport. Any OR exercise would be incomplete, however, without the recognition and logical demonstration of how these sub-problems inter-relate and directly influence each other and therefore the shape of the project as a whole.

The strength of these inter-relationships and the extent to which one sub-problem is constrained by another are not easily identified. The impact of uncertainty only serves to make analysis even more difficult. Uncertainty is, of course, a natural characteristic of coal mining and presents a constant challenge to engineers and analysts alike, but uncertainty is much greater in the particular field of new capacity planning where data is so much more limited and the planning horizon is so long.

This paper is concerned with the subjects of inter-relationships and uncertainty and their effect on the mining strategy in the field of new capacity planning. It makes reference to some of the work undertaken in these fields by the Operational Research Executive of the National Coal Board, United Kingdom. The paper leaves many questions unanswered because although much useful work has been done over the last few years there remain many problems to be overcome. It is likely that questions of inter-relationships, uncertainty and risk will present a challenge to OR Scientists and Systems Analysts for some time to come.

2. Identifying Inter-relationships

It is important at all stages of the planning process to recognise that the facts, data and assumptions gathered or made about some part of the plan invariably influence other aspects of the total plan. Hence the likely recoverable reserves may influence or be influenced by the mining method which in turn may be influenced by the availability of manpower or technological advances. Such connections as these may seem obvious but it is often a temptation to alter one aspect of the strategy without examining the consequences on other aspects. This is more likely to happen when the different sub-problems lie within different specialities.

The Operational Research Executive have developed some models to enable the effects of changes to estimates and assumptions to be quickly assessed. Two examples are briefly outlined: the first is concerned with the inter-relationship between reserves and mining method, and the second between mining method and manpower requirements.

The Geoplan system summarises the size, distribution and quality of reserves but can also be used to examine the link between reserves and mining strategy. This second half of the Geoplan system enables any proposed underground layout to be assessed, given the distribution of reserves by quantity and quality, or, could be used to re-assess a given underground layout if reserves are recalculated, perhaps from more borehole information. Sequences of panels, machine-shifting patterns and assumptions on face advance are input to a computer program which calculates how the faces and sequences advance, year by year, through the grid square summary of reserves distribution. In this way, annual estimates of output and quality from each face can be produced. These are summed, together with calculations of separate dirt production to give estimates of colliery run of mine quantity and quality year by year. If the run of mine forecasts are not satisfactory from the chosen mining layout (for example, there may be a few consecutive years with consistently high ash or consistently low output), a change can be made to the input of the mining layout, or the machine-shifting pattern, to improve the balance between production from the different areas of the take. Alternatively, fresh information on the likely distribution of the reserves can be used to check the suitability of the previously-preferred mining strategy.

A second example is provided by a model developed by the Operational Research Executive to link manpower requirements and the mining strategy. This computer model uses information on face and layout parameters to calculate manpower requirements and productivity. As the mining plan is revised, so the model can speedily summarise the consequences on manpower needs. These revisions may involve changes to face design, layout design, manning patterns, development patterns or advance rates all of which are input to the model. Alternatively, the model may be used in reverse to examine the consequences on output as layout parameters change, given a constant manpower availability.

These models aid the analysis of the interaction between different sub-problems. The figure below illustrates the inter-relationships that are likely to exist in new capacity planning.

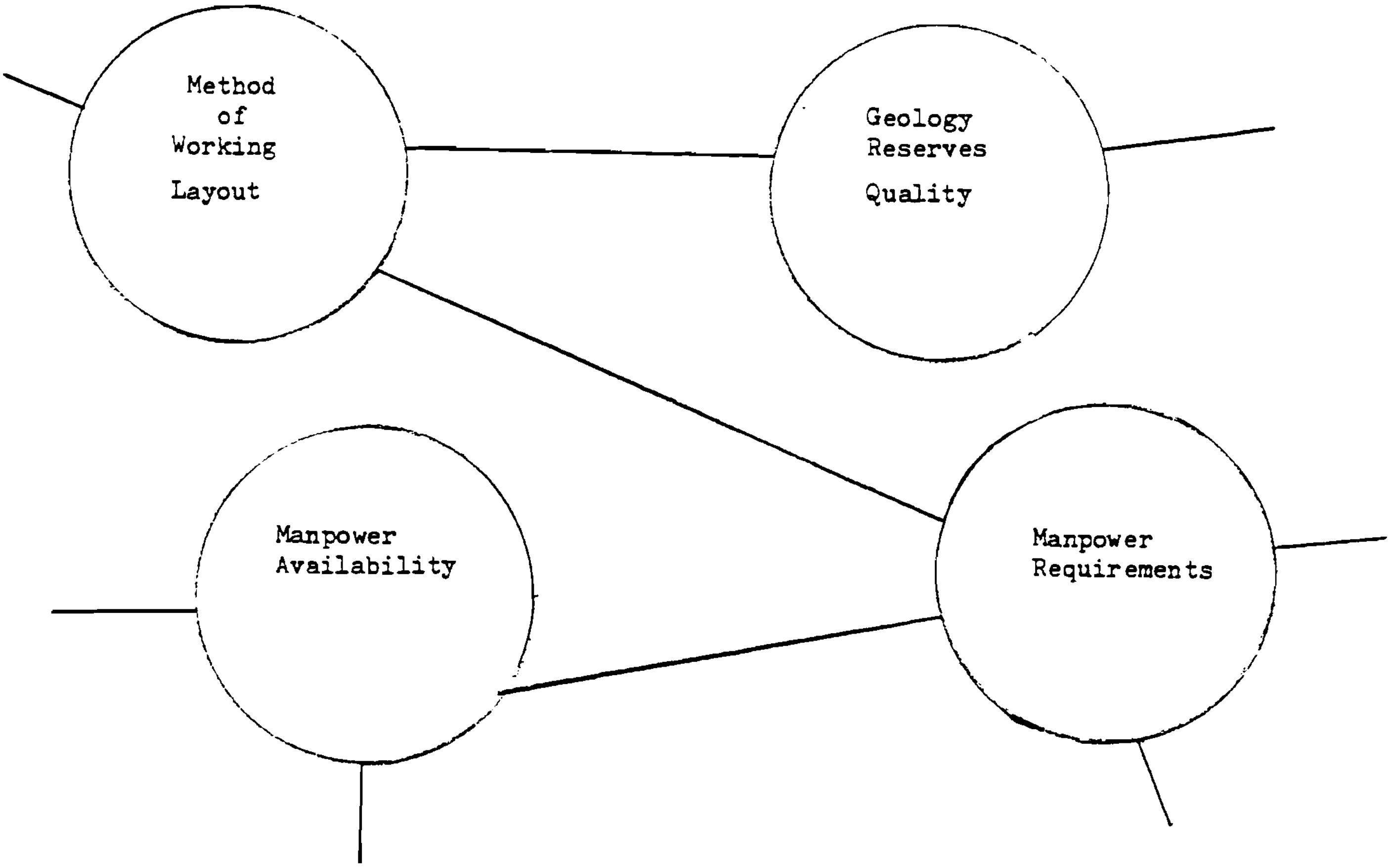

Figure 1 - Inter-relationships of Sub-Problems

The recognition of these connections and, therefore, the need to examine changes to the total plan from changes to one part of it, is not sufficient in itself for the strength of these relationships should also be appreciated. It may be, for instance, that the mining and layout plan will be independent of the extent and distribution of reserves, at least within a fairly broad band. The dependence of the preferred mining plan on having sufficient manpower of the right skills and experience may, on the other hand, be far stronger. Where the inter-relationships are stronger will, of course, vary from prospect to prospect, but their strength should be identified to understand how much uncertainty or risk can be tolerated in each part of the total planning project before it affects the project as a whole. The next section of this paper is concerned with uncertainty, not solely within sub-problem area, but also on how uncertainty in one of these areas may effect the overall project.

3. The Effect of Uncertainty

Much of the work of the Operational Research Executive in the field of new capacity planning has concentrated on encouraging the use of analysis and models right from the very early stages of planning, even when there is paucity of data, and to refine analysis as more information becomes available. This means that potential problems can be quickly identified but carries with it the danger that assumptions and estimates, intended to be no more than that, take on a meaning which bears no relationship to the crude data on which they were based. The first point to make about uncertainty, therefore, is to recognise that it exists and that much of it will never be removed. Inevitably, at some point in the planning process, there will be the need to use central estimates but these should not be treated as exactitudes, at least not without proper understanding of the effect of so doing.

The existence of uncertainty does not preclude effective planning, although it does serve to make the task more demanding. Indeed, it may often be the case that uncertainty within particular features of the plan are of no importance and an important task is simply to identify where uncertainty may be more easily tolerated. Even at an early stage in planning, it is sometimes possible to identify the important components of the plan which may constrain the plan as a whole. These constraints may be capable of being relaxed at a cost (coal quality by spending more on coal preparation) or fixed (total reserves) but in either case it is important to reduce the uncertainty concerning these, since the plan as a whole is limited by them. Figure 2 illustrates the effect of being restricted by manpower availability, and the importance, therefore, of reducing the uncertainty surrounding any estimate.

Uncertainty within one of these sub-problem areas and its effects on other areas may be effectively explored through the use of simple sensitivity analysis. The model which links manpower requirements and mining strategy was described earlier and this can be used, along with other such models,

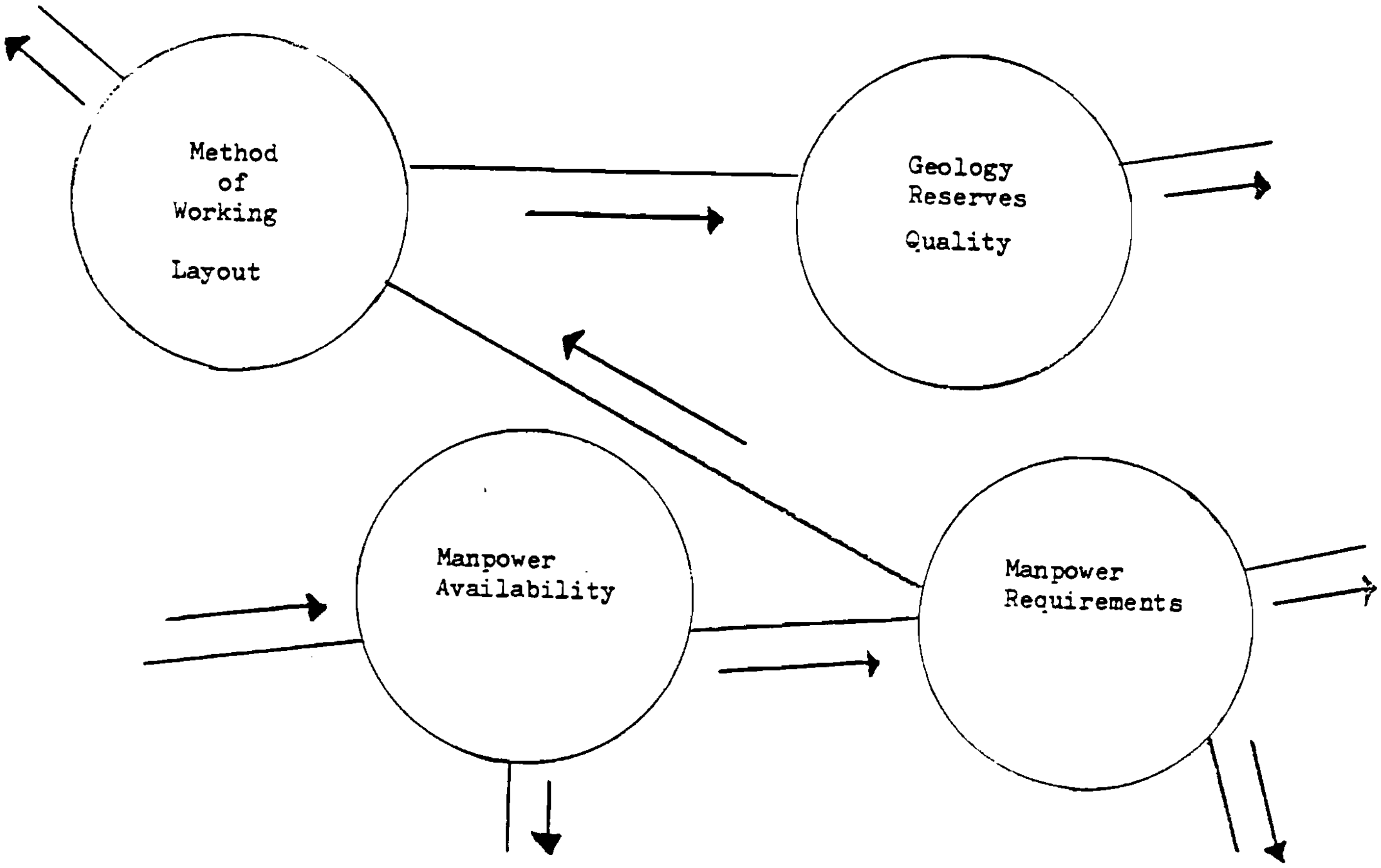

Figure 2 - The Effect of Manpower Shortages

to highlight the sensitive or critical areas of a plan. The example tabulated below, on the effect on manpower requirements of changing mining assumptions, clearly illustrates that some features of the plan are more critical than others in their effect on manpower needs. It is these features where efforts should be made to reduce uncertainty.

Figure 3 - Manpower Requirements : The Effect of Changing Mining Assumptions

Factor	Assumed Value	Effect on Total Manpower of a change of + 10%
Total Saleable Required	7 m tons	+413
Coal From Developments	0.3 m tons	- 18
Extraction Height	2 m	-359
Web Depth	0.61 m	-266
Face Length	240 m	-350
Panel Run	1200 m	- 27
Retreat %	67%	- 16
Face Vend	82.5%	-359
Strips/Shift - Retreat	2.75	-175
Strips/Shift - Advance	2.25	-102
Face Development Advance Rate	4.57 m/day	- 93
Shifts/Retreat Face) including supervision	22	+182
Shifts/Advance Face)	27	+110
Shifts/Development Team)	4	+103
Shifts/Man Year (inc. Overtime)	212	-359
Overtime %	15%	+ 52

One of the attractions of sensitivity analysis of this form lies in its simplicity - once a model has been devised and tested which accurately links different sub-models, it is an easy matter to clearly and concisely demonstrate the relative importance of accuracy of the different components. Its limitation is that it does not indicate the likelihood of any of the factors changing by a certain percentage. Full risk analysis however, takes account of these likelihoods and enables the robustness of the project as a whole to be tested. In such analyses, the Operational Research Executive have used money as the unit of measurement - not necessarily because profitability or return-on-capaital are the sole basis for assessment - but because it is convenient to express the various factors in terms of one common unit. Full risk analysis gives management a complete summary of the confidence that can be attached to particular outcomes for a given project but the full potential lies when different options are compared. Depending on management's attitude to risk, it is possible that the consequent decisions taken may be completely different from those that would have been taken conventionally.

Having identified where uncertainty is greatest and where uncertainty matters most, it often falls on management and engineers to decide how to most effectively reduce the uncertainty. Here too, however, there is potentially a large role for the OR Scientist or Systems Analyst in advising how resources - money and time - can be best deployed. The research of the Operational Research Executive in this field is somewhat fragmented and much work remains to be done. Studies have been undertaken on such matters as borehole spacing, on the benefits of seismic exploration, the factors influencing manpower wastage rates (and therefore recruitment needs) and the assessment of investment in new technologies, but much of this work is at an early stage. In the UK at least, this is a problem-area where many questions remain to be answered.

Inevitably, uncertainty can only be reduced and never removed: there will remain a level of unavoidable uncertainty. In order to test how robust a plan is likely to be, the Operational Research Executive have developed a number of approaches which rely extensively on simulation: three of these are described below.

The first of these, Geosimplan, is concerned with the uncertainty about the location of geological hazards in the coal measures and their effect on the mining layout strategy. These hazard-faults, washouts or broken ground - may be too small to be detected from surface exploration but large enough to cause producing coal faces to be halted unexpectedly, resulting in serious financial consequences. This risk may be reduced in several ways, but these methods of risk reduction (spare face capacity, exploratory tunnelling, in-seam seismic) are themselves expensive. Geosimplan was developed with Geology Branch of the National Coal Board to help to overcome the problems of imperfect geological knowledge by testing the chosen strategy, or alternative strategies, against the likely geological intensity. The strategies are evaluated by simulating their operation (by hand) against patterns of geological hazards, produced on the basis of information gained from exploration and (if they exist) from surrounding coalfields. A manager acts as a decision-maker in this process, the nature of 'future' geology being unknown to him until hazards are encountered by faces or roadways. Deficiencies in any strategy can thus be identified and the strategy modified and re-tested. The features of the strategy of most interest will vary from site to site but invariably include the number and concentration of faces to achieve a desired output and the balance of resources between development and production.

In contrast to the hand-simulation approach of Geosimplan, a series of large and complex computer models have been developed to assist in coal clearance planning and design. These models, SIMBELT and SIMBUNK, simulate the production of coal at the coal face, its movement underground to the pit bottom and its passage to the surface via the shaft or drift. They take into account variabilities in coal flow and interaction between coal faces, and hence demonstrate where bunkers will be required to smooth flow, and what the capacity underground belts and bunkers should be. The models have been further developed to handle problems of dirt control, through underground separation of the mineral, and to test sophisticated systems of central belt and bunker control made possible by recent technological advances.

Finally, a further illustration of the use of simulation is provided by the models developed to analyse surface facilities. Unlike the problems associated with the movement of coal underground, the surface problem is typically concerned not only with variability of flow but also variability in quality. Models have therefore been developed to examine homogenising, blending and washing facilities to ensure that these facilities can cater for the likely variability in quality and quantity at the minimum cost.

4. Summary

This paper is concerned with inter-relationships and uncertainty in new capacity planning; it is not intended to be a definitive statement of how such problems should be tackled, although it summarises some of the approaches used by Operational Research Executive of the United Kingdom. The main arguments developed are:

(i) Inter-relationships should not be ignored - it is important to logically follow through the consequences for the plan as a whole of making changes to one part of it.

(ii) One way of doing this is to develop models which link sub-problem areas, and to promote their continued use as more information becomes available.

(iii) Uncertainty is inevitable in new capacity planning, but the level of uncertainty that can be tolerated will not be the same across all aspects of the planning strategy.

(iv) Sensitivity analysis is a simple but powerful way of identifying the consequences of different levels of uncertainty within each sub-problem and between sub-problems. Later, full risk analysis can be used to assess the project as a whole.

(v) It is important to identify where efforts should be made to reduce uncertainty. There is potentially a large contribution to be made by OR Scientists and Systems Analysts in advising how this uncertainty may be most effectively reduced.

(vi) Some uncertainty is unavoidable - one way of testing the robustness of the plan to the risks inherent in new capacity planning is to use simulation models to examine what insurance is necessary and what risks can be carried.

NEW MINES PLANNING AND THE ASSESSMENT OF ENVIRONMENTAL FACTORS

E.J. Allett*

Introduction

Increasing public awareness of environmental issues has put great pressures on developers to demonstrate that their new projects are environmentally acceptable. In the USA there is a statutory requirement on developers to make environmental impact statements about any proposed new project. There may soon be a similar requirement for large projects by developers in the member states of the EEC. Although there is no legal requirement to do so in the UK, the National Coal Board (NCB) along with some other developers produce a description of the possible environmental impacts of major projects such as new mines.

In order to anticipate and if possible avoid environmental problems, the developer needs to consider the environmental factors through every stage of planning a project. For example, the purpose of the NCB's feasibility study is to decide whether to proceed with the planning of a new mine. During this study the Board consider the broad environmental characteristics of the prospect and their possible influence on the project. After the feasibility study, detailed planning of the proposed project can begin and environmental impacts considered in greater depth. At any stage of planning, decisions have to be made which are influenced by environmental factors. Studies to help provide the answers should obviously be tailored to the particular decisions but they will generally involve the following steps:

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*The author is employed in the Operational Research Executive of the UK's National Coal Board. It must be emphasised however that the views expressed are those of the author and not necessarily those of the National Coal Board.

1. The identification of those environmental impacts which have a bearing on the decision and the measurement of them in some appropriate manner.
2. An assessment of the impacts and of their effect on the decision to be made.

Neither step is easy but the second can be particularly difficult. This is due to the fact that some impacts are of a highly subjective nature and that trade-offs have to be made between factors which are not measured on the same scale.

In the next section of this paper, some of the difficulties of identification and measurement are discussed with reference to the use of impact matrices. In the third section the sieve technique is described. This has been used by the NCB to help locate mines in a new prospect. It provides an example of how the particular difficulties of assessing the effect of environmental impacts were overcome for the site selection problem.

The Identification and Measurement of Impacts - Impact Matrices

The first task is to identify all the impacts which might have a significant influence on the decision to be made. This is not a trivial task, especially for such a large and complex development as a new deep coal mine.

Impact matrices can provide a useful checklist for identifying all the impacts that a new mine may have on the environment. They are commonly used as a framework for making Environmental Impact Statements in the USA. Figure 1 shows an attempt at producing an environmental impact matrix for a new deep coal mine. The rows represent the activities which will take place during the life of a colliery and the columns represent the environmental characteristics of the area around the mine. Where an activity is likely to interact with an environmental characteristic a cross is marked in the appropriate box. For example, the recruitment of men for a new mine is an activity. This may have beneficial or adverse impacts on the local employment, the housing or the community services situations, depending on the characteristics of the particular locality.

The activities can be divided according to whether they occur before, during or after operation of the mine. They can also be divided into those activities carried out by the developer and those spin-off or secondary activities which are a necessary part of the project but which are usually carried out by someone other than the developer.

Indeed all activities can be regarded as being spin-offs from the fundamental activity of extracting coal from under the ground. They can be imagined as branching trees of activities, any one of which may have associated environmental impacts. There are many possible ways of listing the activities but since it is done only to help identify impacts, it does not matter which way is chosen provided that all the impacts are identified.

Consider another, perhaps less obvious, example. Subsidence, though not usually called an activity must not be considered to be an impact. If it is, then some real impacts, namely the possible changes in the landscape and the hydrological characteristics, the possible consequential changes in land use and ecological features and the possible damage to surface structures, might be missed. Also, as in the example of recruiting the men for a new mine, the predicted amount of subsidence on its own does not tell us whether the impacts are beneficial or adverse - the predictions have to be applied in the local context.

The impact matrix illustratesthe fact that impacts occur because of interactio between the project and the environment. Similarly, the size of the impacts, as the subsidence example shows, depends upon both the project and the local environment. In general, the activity giving rise to the impact (e.g. the number of men recruited, the amount of subsidence) is first estimated for the particular project and the result is applied in the particular local context. A relatively straightforward example is that of noise intrusion. The sources of noise associated with the mine are identified and their size estimated, using standard measuring techniques. The number of affected people is estimated, based on the local demography and topography. The size of the impact is then assessed by reference to widely accepted levels of acceptability for noise. Visual intrusion is far more difficult to measure. The dimensions and design of the mine may be known in great detail and it is fairly straightforward to estimate the number of people who can see the mine, but the size of the impact depends on people's reaction to what they see and there is no widely accepted scale of measurement that can be used to measure this - nor perhaps can there ever be.

Other difficulties arise with the general approach for measuring impacts described above, when the links between activities and impacts are not properly understood. Taking an example from coal utilisation, the relationships between sulphur dioxide and particulate emissions and various detrimental impacts are barely understood let alone quantified. For this reason it is difficult to see how the impacts can be measured. In fact what happens is that standards are imposed on the level of the activity rather than the impact, and the question of the link between them is avoided.

We have observed then that there are a variety of problems associated with measuring environmental impacts. The state of the art does not have an answer to all of them, but as the pressures for environmental impact assessments increase so do the efforts to find acceptable ways of measuring all impacts.

Assessment of Impacts - Sieve Analysis

When choosing a strategy for exploiting a new prospect, probably the single most important decision affecting the size of the impacts on the environment, is that of selecting the mine site(s). The problem of finding the best site can be broken down into two stages. Firstly, areas are identified in the prospect which might contain several suitable sites. These areas are chosen using both underground mining and surface criteria. Secondly, the precise sites are chosen, possibly with the co-operation of local groups affected by the decision.

Sieve analysis is a technique for reconciling the mining and environmental factors when choosing the areas for later scrutiny. It proceeds by identifying the relevant criteria or factors, dividing the prospect up into a grid of say one kilometer squares and giving a code to each factor in each square. The grid of codes for a factor is called a sieve. By adding the codes up, a total score is produced which gives an indication of the relative suitability of each square for siting a mine. An impressive visual presentation of the results can be made by assigning different shades of grey to the codes and shining light through superimposed slides of the sieves. The more suitable squares show up lighter on the screen (see Figure 2).

The technique is tailored to the specific problem of identifying the more suitable areas within the prospect. It only considers those factors which have a bearing on the preferred location of a mine. Figure 3 lists the factors used in an application of the technique to the NCB's North East Leicestershire Prospect, and describes the criteria used for coding them.

The factors were carefully chosen to cover all the relevant impacts, yet keep the measurement and coding task simple. This is necessary because the exercise is normally being carried out at a very early stage of planning, perhaps even before the developer has decided whether the project is financially attractive. In these circumstances it could be a large waste of effort to do detailed studies of the whole prospect at that stage. For example notice that there is no sieve representing the impact of noise from the mine, yet clearly it is a factor which somehow should be taken into account. A detailed survey could be made of the whole prospect by assuming the mine to be sited in each grid square and measuring the noise impact. Alternatively, the impact could be estimated by counting the number of people within a certain distance of each grid square.

Even this would involve considerable effort so a sieve was introduced which simply reflects a preference for siting the mine away from population centres. The same sieve represents to some extent the dust and visual intrusion factors.

The method of adding the effects of the factors could be criticised for being too simple. The results are very sensitive to the choice of coding system and the method does not recognise that some factors are more important than others. The technique could be modified to cover some of these criticisms but only at the expense of making it more complicated. However, as argued in the previous paragraph, too much sophistication at such an early stage of planning could be wasteful.

Since there is no absolutely correct answer to the problem of choosing a mine site, no technique however complicated can find it. Nevertheless, the problem has to be solved and this is usually done by debate. The sieve technique can certainly help direct and inform that debate by providing a framework, which identifies the significant factors, and a set of basic information.

Conclusions

Developers are finding that environmental factors must be taken into account in an increasing proportion of the decisions that they make. Studies to help do this will usually involve identifying and in some way measuring the relevant factors and then performing an assessment of their effect on the decision to be made. Each study must be carefully tailored to the problem.

In this paper we have highlighted some of the difficulties in carrying out such studies and referred to two techniques which have been used to overcome them. There is one fundamental difficulty that can never be overcome however, and that is the highly subjective and emotive nature of environmental issues. The author believes that OR must stop short of trying to produce "correct answers" and be satisfied with providing better data and a framework for structuring the debate.

Figure 1

Environmental impact matrix for a new deep coal mine

COLLIERY ACTIVITIES	AREA CHARACTERISTIC	ENVIRONMENTAL CHARACTERISTICS	Land use	Landscape quality	Visual intrusion	Noise level and vibration	Air quality	Water quality	Hydrological characterisitcs	Ecological features	Population & employment structure	Volume of road traffic	Stability of surface structures	SECONDARY ACTIVITIES	Provision of houses	Provision of community services	Provision of electricity	Provision of potable water	Provision of industrial water	Provision of railways	Provision of roads
A. CONSTRUCTION PERIOD:																					
Recruitment of Construction Workers											/				/	/					
Site levelling			/		/	/	/		/	/											
Ground freezing						/			/								/				
Shaft sinking						/			/								/				
Waste disposal from shaft & site			/	/	/	/	/	/	/	/											
Initial Screening				/	/	/			/	/											
Road transport of men					/	/	/					/									/
Road transport of materials					/	/	/					/									/
Construction of surface structures			/	/	/	/	/		/	/							/				
B. PRODUCTION PERIOD:																					
Manpower & Staff recruitment											/				/	/					
Road transport of men					/	/	/					/									/
Road transport of materials					/	/	/					/									/
Rail transport of materials					/	/	/													/	
Mining activities underground)									/							/	/		/		
Subsidence)			/	/					/	/			/								
Operation of shaft equipment						/											/				
Conveyor transport of coal					/	/	/										/				
Despatch of coal by road					/	/	/					/							/		/
Despatch of coal by rail					/	/	/													/	
Coal treatment						/	/	/									/		/		
Stocking			/		/		/	/													
Local tipping of dirt			/	/	/	/	/	/	/	/											
Rail transport of dirt					/	/	/													/	
Disposal of tailings			/	/				/													
Screening				/	/	/	/		/	/											
Landscaping				/	/	/	/														
Admin.stores & workshop facilities																/	/				
Provision of baths & catering																	/	/			
C. POST PRODUCTION PERIOD																					
Land rehabilitation			/	/					/	/											
Relocation of manpower											/				/	/					
SECONDARY ACTIVITIES																					
Provision of houses			/	/	/	/			/	/											
Provision of community services			/	/	/	/		/	/	/											
Provision of electricity				/	/																
Provision of potable water									/												
Provision of industrial water									/												
Provision of railways			/	/	/	/				/											
Provision of roads			/	/	/	/			/	/											

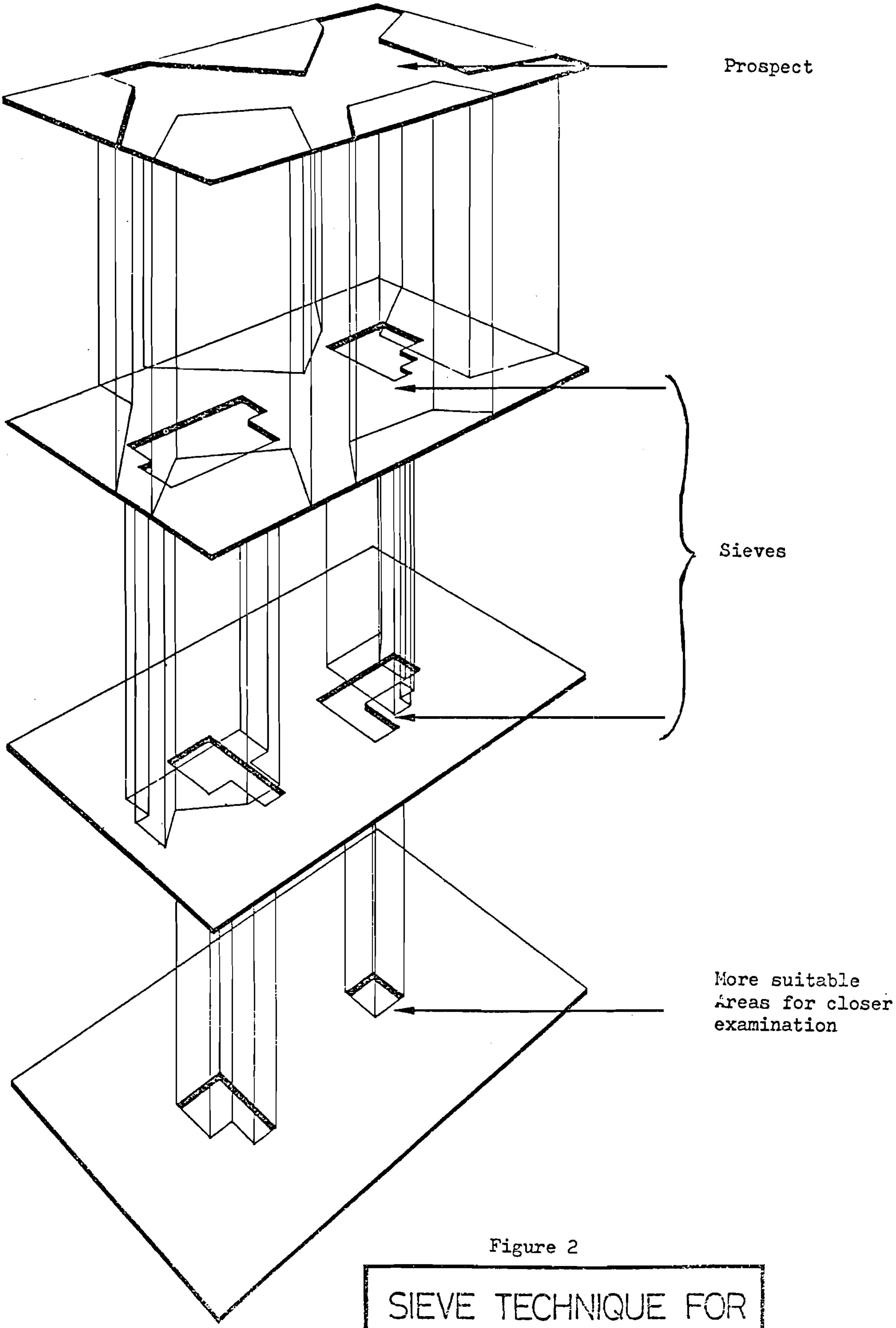

Figure 2

SIEVE TECHNIQUE FOR SITE SELECTION

Figure 3 Table of Sieves used for the NCB's North East Leicestershire Prospect

Factor	Description
Road access	Three code values reflecting accessibility for miners from the main population centres around the prospect.
Rail access	Two code values reflecting the approximate cost of providing rail connections to the new mine. Areas within 2•5 km. of the rail network are preferred.
Services	A map showing the position of electricity lines and oil and gas pipelines.
Ground slope	Areas of the prospect with slopes greater than one in 25 would need more ground preparation before construction.
Vegetation and wildlife habitat	Avoid areas more suitable for wildlife such as woodlands, wasteland and watercourses.
Agricultural land potential	Avoid the better agricultural land.
Low land capability	Avoid areas with little soil, where tip restoration or site preparation could be more difficult.
Proximity to settlements	Avoid mine buildings within 1 km. or tip construction within 0•5 km. of centres of population.
Landscape quality	Avoid area of relatively high landscape quality.
Statutory designations	Aim to keep the mine away from conservation areas or sites of special scientific interest.

SYSTEMS APPROACH TO COAL INDUSTRY DEVELOPMENT ANALYSIS AND FORECASTS

L.A. Kaforin
V.B. Moskvin

The coal industry of the USSR has been rapidly meeting ever increasing needs of the national economy in solid fuel and feedstock for the metallurgy. Coal output in the USSR increased from 624.1 million tons of run-of-mine coal in 1970 to 718.7 million tons in 1979. Over the same period the share of open cast coal mining expanded from 26.7 to 36.0 per cent. The technical level of production has been improved, percentage of coal output from fully mechanized coal faces in seams dipping to 350 increased from 29.9 to 72.3 per cent, the level of mechanized loading of coal and stone in driving development headings reached 80.8 per cent in 1970.

At open cast mines over 40 per cent of coal output are produced with highly efficient bucket wheel excavators.

Coal output increaze over the same period has been totally acheived due to productivity improvements and substantial reduction of manpower.

Future development and improvements in production efficiency in the coal industry alongside with the expansion of productive capacities based on new construction projects, reconstruction and technical reequipment are closely connected with the necessity to improve the utilization of production potentials.

Under such conditions an important tool is the systems analysis of the coal industry development the main aims of which are the following:

- study of development trends;
- detailed study of production and economic results obtained at production units and mines;
- study of causes of deviation of actual results from plan targets;
- investigation and qualitative assessment of impacts exerted by natural, engineering , organizing and social factors on final indices of the coal industry and its subdivisions,.

The theory of technical and economicanalysis in Russian mining is based on investigations carried out at the beginning of the 19th century by B.I.Bokiy, a mining engineer and an outstanding scientist. It were those studies that marked the introduction of production analysis methods in mining based on econometric simulation models.

The trend in technical and economic analysis discovered by B.I.Bokiy was further revealed in works written by prominent Soviet scientists, such as L.D.Shevyakov, A.S.Popov, P.Z.Zvyagin, M.I.Agoshkov, A.M.Kurnosov, etc.

Computers have become a new impetus for the development of this trend in analysis. Computers made it possible to change over from econometric models with one to five independent variables to models dimensions of which are measured by dozens and hundreds of variables. In such conditions the level of the systems nature of analytical studies has been considerably improved.

The complete systems nature of analysis in the coal is stipulated by the appporiate organization of analytical work in which practically all subdivisions, taking into account the competency of each of them, take part in the analysis of the results obtained by enterprises, production units and the industry as a whole.

For instance, within the major departments of the USSR Ministry of the Coal Industry Headquarters special divisions to analyze the availability of mining mashinery and equipment and productive capacities and a section for summary analysis have been set up, in the other departments analysis problems are tackled by the most qualified specialists particularly appointed for this purpose.

In production units, branches for analysing production and economic activities have been formed and the procedure of enlisting production and technical services has been outlined.

In some of the production units analytical work is based on activity networks in which analysis tasks, sequence and terms of solution are determined.

In addition to organizing measures, the systems nature of analysis in the coal industry is also ensured by including practically all spheres of productive and economic activities which are closely interconnected and integrated.

At the Ministry Headquarters and production unit levels main trends in revealing potentials , which are taken into account while performing the analysis, have been outlined, these are as follows:

- main technical and economic indices for every quarter and year(summary complete analysis).
- fulfillment of the coal output plans as for mining methods, coal types and grades and mining and technical targets;
- utilization of productive capacities at underground and open-cast mines and coal preparation plants;
- fulfillment of plans for coal preparation and coal quality;
- fulfillment of plans for products realization;
- introduction of advanced technology, mechanization and automation of production ;
- operatoion and utilization of the major mining mashinery and equipment;
- fulfillment of plans for productivity and impacts fof technological progress on productivity improvements;
- expenses from the wages fund; formation and utilization of economic incentive funds;
- dissimination and efficiency of the advanced experience;
- utilization of major funds;
- fulfillment of plans for production costs and profits;
- utilization of coal reserves;
- manpower deployment;
- technical and economic indices of capital construction .

Alongside with the above mentioned major subjects, the analysis sections at the production units tackled the following problems:

- performance data obtained at high-output coal faces, analysis of delay causes, fulfilling the schedule of developing and commissioning coal faces; mechanization of ancillary operations - directors for production take part in this work;

- introduction of technological layout data at completely mechanized coal faces; improvements in coal getting technology, fulfillment of plans for development operations - technical directors take part; directors for economics take part in: - status and utilization of turnover capital, assessment of economic consequences of non-fulfilling the plan for major production indices; fulfilling work quota targets;

- central accounting office staff take part in: - detailed analysis of operating costs on separate elements;

- staff under the chief mechanical enginner takes part in: - - analysis of causes of exceeding consumption of electric power and fuel; conditions of planned preventive maintenance, etc.

Research Institutes take an active part in technical and economic analysis of enterprises operation in the coal industry; these Institutes carry out appropriate studies according to a common coordinating plan under the guidance of the central coal-industry Institute for economics (TSNIEIugol).

For the sake of extending the analysis and use of comprehensive report information, computers and computer methods are being applied on a wide scale.

In the computer centers under the Mininstry of the Coal Industry of the USSR and production units a wide range of problems on the following major subsystems of the coal industry automated system of management control are being tackled under the guidance of the special Institute for Management:

- technical and economic planning;
- planning, accounts and analysis of wages and salaries;
- payments for coal;
- operational accounts and control of main production technology;
- purchasing and stores;
- planning and deployment of personnel;
- accounting;
- control of products quality;
- control of capital construction and coal mining machinery engineering, etc.

A considerable proportion of problems of accounting nature and the results obtained on the basis of such problems, extensive systemized reports are a reliable basis for extended analysis of production and economic data.

Analysis is based on extencive state statistical reports at all levels of management. In addition to these, presentation of a system of operational reports has been organized according to the instructions issued by the Ministry of the Coal Industry of the USSR which fully reflects current results obtained at each enterprise and production unit.

According to periodicity of presentation, operational reports are divided into daily, weekly, decade, monthly, quarterly, and half-yearly reports.

Every day production units present to the Ministry Headquarters data on fulfillment planned targets for coal output and treatment, causes of deviations from planned figures.

Weekly reports contain data on manpower number and deployment in main operations, coal reserves available for open cast mining, volume of overburden removed, data on fully mechanized coal faces of collieries.

Monthly operational reports contain the most detailed information on operation of each production unit, i.e. mining and economic data.

Every quarter coal production units present data on fulfilling job quotas, wages and salaries, fulfilling organizing and technical measures on fuel and electric power savings, operation of railway transport, development of capital construction.

To provide operational management control of productive activities on the basis of statistical and operational reports the Coal Ministry Headquarters issues a monthly systematized survey in which data and indices on the industry as whole, main coal basing and all production units are summarized.

Similar monthly surveys are issued on capital construction which present totals on commissioning fixed assets, production capacities, housing, labour indices.

In addition to monthly surveys, quarterly bulletins are issued which systematize data on a wider range of indices, for instance, economic results obtained by production units are analyzed alongside with tehchnological data.

Data contained in statistical reports are summarized and systematized more thoroughly in annual analytical reference books reflecting the development of the coal industry, coal fields, regions, production units and each enterprise.

Practical application of systems analysis in the coal industry is based on specially developed methods for technical and economic analysis in production units and enterprises. These methods contain specific recommendations and algorithms for performing computer-aided analysis on the following lines of productive and economic activities:

- coal output, development operations, mechanization of coal face operations and drivage of development headings;
- utilization of productive capacities;
- coal preparation - qualitative characteristics of coal extracted and outloaded, coal treatment and balance of preparation products;
- economic data, productivity, production costs, proceeds, profits and profitability of production.

In each section of analysis methods forms of analytical tables, calculation formulas (models, algorithms) have been developed providing for qualitative assessment of impacts of various interrelated and interdependent geological, engineering and organizing factors on the level and change of production efficiency indices.

Results of comprehensive analysis are the basis for developing short- and long-term plans for coal output and improving technique and technology of production in the coal industry as a whole, coal basins, production units and enterprises.

Peculiar features of mining are the necessity of detailed exploration of minerals (which requires considerable time), very long cycle of setting up and developing productive capacities at mines comprising time for planning, construction and developing rated capacities of mines, large scope of capital construction of infrastructure projects, education and training of personnel - all these require planning and forecasting coal industry long-terrm development.

At present optimum layouts of development and allocation of coal industry enterprises up to the year 2000.

Availability of vast workable coal reserves in different regions of the USSR, expected high rates of development of various fuel-consuming branches of the USSR national economy predetermine the necessity to thoroughly forecast on a scientific basis prospects for the coal industry development.

On the basis of the systems approach and taking into account variety of interrelations between coal consumers and mines, requirements for coal quality, feasible prospects of developing productive capacities in cooperating industries (construction, machinery engineering, power, transport, etc), main principles of the methods of economic feasibility studies of development and allocation of coal industry enterprises for long-term future have been worked out.

The above mentioned methods provide for the following:

- preparing a scientific basis for feasibility studies of the draft plan for the coal industry development for 1981-1985;
- coordination of the 1981-1985 plan and the expected development of the coal industry for long-term future;
- revealing marginal capital investements and material resources;
- complex consideration of prospects of main branches within the coal industry, more comprehensive economic feasibility studies of development of such branches as coal mining machinery building, material basis of construction, non-production construction (housing, etc);
- comprehensive study of such factors as product quality, improving the utilization of fixed assets, capital investments for environment protection, costs of infrastructure projects, social problems;
- performing alternative investigations depending on the level of capital investments allocated for the coal industry;

In working out main trends and layouts of the coal industry development it is expected to provide for productive capacity increase, first of all , due to technical reequipment and reconstruction of existing enterprises.

Main trends and layouts of coal industry development should reflect the following interrelated subjects:

- scientific and technological progress which is determining factor in improving the efficiency of production and productivity;

- current state and prospects for developing mines and other enterprises (including new construction projects);
- stream-lining management control of the coal industry;
- environment protection;
- coal industry needs in major machinery and equipment, material and labour resources;
- main technical and economic indices (actual and cost).

The most important condition for feasibility studying prospects of the coal industry development is to determine the needs in coal fuel.

Studying the needs in coals of different type and quality is performed by a balance method providing for more profound outline of the share and proportion of fuel industries, in particular coal, in long-term development and allocation plans.

Assessment of needs in steam coals is effected with due regard for the following:

- long-term fuel-and-power balance of the country (multi-alternative studies);
- steam coal resources available for mining with present technical means calculated on the basis of coal output for each mine;
- economic assessment of coal resourses for each enterprise;
- economic indices of utilization of coals from different coal fields in the national economy with due regard for coal quality, production cost , treatment, transport and utilization by consumers;
- advantages of setting up large fuel-and-power complexes based on open cast mines with vast coal reserves.

The needs in coal are calculated by major consumers - thermal power stations, industrial and regional boilers, domestic sector, agriculture, construction industry; these needs are assessed in bituminous and brown coals, anthracites, graded fuel and briquettes.

In assessing the needs in coal for coking purposes prospects of the development ferrous and non-ferrous metallurgy, machinery building and chemical industry are taken into account. Needs in coal mix for coking are calculated for each coke-and-chemical and steel plant with due regard for the prospects of their development, technologically feasible alternative mixes for individual plants or group of plants are revealed.

Particular attention is being paid to alternative options of coke production from weakly-coking coals.

Prospects for the development and allocation of coal mining and treating enterprises are based on the expected scale and scope of the coal industry development with due regard for the results of optimization calculations.

Criterion of optimality is accepted as the minimum of aggregate capital and operating costs for exploration, construction of a coal mining and treating enterprise, transport of coal to the consumer and coal utilization.

When optimizing within a coal basin a simplified criterion is possible in which costs for coal transport within the basin and coal utilization are not taken into account when comparing alternative options costs are calculated for final products, i.e. for coals used for electricity generation - per 1 ton of coal equivalent, for coals sent to coking - per 1 ton of concentrate; this allows for different qualitative coal characteristics (ash content, moisture, calorific value, concentrate yield) to be taken into account more comprehensively.

Forecasts of the coal industry development, in addition to the development of productive capacities at underground and open cast mines and preparation plants and the appropriate construction organisations,

include prospects for the development of -

- industrial transport at coal industry enterprises (railway, road, conveyor, pipeline), requirements for rolling stock and other equipment are defined, scale and terms of constructing roads and railways, pipelines etc. are determined; machinery building factories and workshops with evaluation of products and production structure, technological progress in coal mining machinery building, specialization of factories;
- electricity generation with the assessment of power, fuel and water consumption;
- measures on environment protection including measures on minerals conservation and rational extraction of coal, as well measures on environmental control(treatment of industrial effluents to prevent water pollution, cleaning of dust and gas emmissions to the atmospheres, mined land reclamation);
- improving miners' health and safety;

- methane drainage, dust control, measures to prevent dynamic phenomena - sudden outbursts of coal, rock and gas, rock bumps, creation of standard climatic conditions in mine workings at deep-level mines, fire protection, etc.

Main trends of research in the field of engineering, technology and economic efficiency of coal mining and processing are being developed to provide the expected development and production efficiency improvements in the coal industry.

Over the recent years measures aimed and improving planning have been worked out in the USSR.

One of the major conditions of solving this problem is the balance between the state plans of economic and social development.

In order to achieve this aim in forecasting the coal development of the national economy branches, and in particular the coal industry, it is necessary to apply a qualitatively new approach to the optimization of characteristics and parameters of individual enterprises, choice of alternative options of the projects development and allocation, calculating the rates and outlining the trends in the cooperating industries, providing labour resources, solving social and well-being problems, etc.

Research and development organizations in the USSR coal industry carry out investigations for methodical provisioning of this important problem and improvements in the systems approach to forecasting the coal industry development.

FORECASTS OF PARAMETERS AND CONDITIONS FOR DEEP-LEVEL MINING IN COAL MINE PLANNING

Theory and Practice of the Development of Automated Coal Mine Planning Systems

Dr. A. Miteyko
Dr. K. Kuznetsov

Forecasts of parameters and conditions of deep-level mining in coal mine planning come to a problem of mathematical programming which is generally formulated in the following way: to find out an ordered set of project solutions being optimized $X^* = \{X_{ij}\}$ which is a subset of admissive realizations $X^* \in X$ in particular geological and social conditions and corresponds to the objective function extremum $C(X, Y, Z, \theta)$ under the following constraints:

$$X_{ij} \in X > 0,\ Y_{ij} \in Y > 0,\ Z_{ij} \in Z \geqslant 0,\ \theta_{ij} \in \theta \geqslant 0$$

and meeting the condition $\Phi(x) = K_2$, where X - a set of admissible project solutions corresponding to a particular combination of parameters under study and characteristics of the enterprise;

Y - a set of geological characteristics of a deposit section;

θ - a set of socio-economic conditions of the mine operation;

Z - a set of admissible non-optimized project solutions;

i, j - indices of a variable and its current value, respectively, $i = 1, 2, \ldots n$; $j = 1, 2, \ldots m$;

K_z - constraints, $z = 1, 2 \ldots q$.

Sizes of a mine take, thickness and lifetime of a mine, as well as its type (individual or amalgamated) and method of reconstruction are determined in realizing a computer-based model of the integrated development of a particular region of coal mines. That is why optimized solutions in planning individula mines include the following:

- methods of opening the mine take and its parts, layout of opening workings;
- methods of developing the mine take and its parts;
- mining systems;
- layouts and means of mechanization of production processes;
- patterns and methods of realization of the mine take and its parts;
- layout and order of grouping coal seams;
- layouts and means of underground and surface transport;
- patterns and means of methane drainage, air conditioning, water drainage and stowing;
- layouts and types of shaft winding;
- distances between its levels;
- sizes of blocks and winning sections along the strike;
- number of levels and blocks within the mine take and under working at a time;
- number of panels, winning sections, levels, sublevels and coal faces in the seam and under working at a time, etc.;

Number and types of decisions being optimized are established by the planner on the basis of feasibility studies and analysis of technological layouts and parameters being optimized. In this case, a problem of compatibility of separate solutions and a graph of alternative solutions is worked out (fig.1).

Choice of optimum project solutions is based on developing and realizing a computer-aided model of a construction or reconstruction project. Minimum of marginal specific capital and operating costs is accepted, at any rate, as optimality criterion; these costs are calculated in accordance with the recommendations of the coal industry instruction on defining the economic efficiency of capital investments. Dynamics of capital and operating cost is being taken into account within the period of mine construction and operation. Taking into account different time of incurring capital and operating costs in alternatives under comparison, they are reduced to a base period, i.e. the beginning of the coal mine construction. With a view of the inadequate "sensibility" of the given criterion while changing project solutions (which is expressed in the "poorly defined" optimum zone), in a number of cases a system of additional criteria is to be introduced in order to choose the optimum alternative option, including the following:

- new mine planning - the level of specific capital costs and the index of production profitability;
- in planning the recinstruction of existing mines - specific capital investments for capacity expansion, the index of production profitability and the degree of utilization of fixed assets;
- in planning new levels at existing mines;
- the profitability index.

Input data are accepted as follows:

- data on the deposit (sizes of mine takes along the strike and down the clip, number of working and non-workable coal seams; distances between the seams and from the surface to the upper boundary of the mine take, water in-flow to the mine, availability and configuration of protective pillars);
- data on coal seams (thickness, type, gas emissinn rate, water in-flow, liability to sudden outbursts and fires, dust content, tectonic faults, ash and volatile matter content in coal, volume weight of coal, cutting strength of coal, etc.);
- physical and mechanical properties of adjoining rock;
- data on mine workings (minimum and maximum cross-sections, types of supports, coefficient of aerodynamic resistance, methods drivage, maintainance and protection, advance rates, etc.);
- data on means of mechanization of main and ancilliary technological processes;
- standards on planning;
- a complex of socio-economic conditions (patterns of mine operation, cost indices on object and production processes, depreciated cost, price-lists and tariffs for fulfilling various kinds of work, etc.).

An econometric model of a mine project is a system of interrelated (from an information viewpoint) engineering, economic and optimization tasks (fig.2), the computer-aided realization of which allows to select optimum (according to the accepted criteria) combination of characteristics and parameters of an enterprise under study with given constraints.

The Objective function is presented in the form of a minimizing (maximizing) algebraic expression of a sum of costs (effect) for individual production processes and operations.

Costs (capital, operating, labour) for production processes are calculated on the bases of cost indices. Cost indices are functional dependencies of costs (for individual operations or technological processes) from geological and social conditions, as well as parameters and characteristics of mines.

In complex optimization of project solutions for deep-level coal mines, costs are taken into account for the following:

- drivage and maintainance of mine workings within the period of construction and operation;
- coal face operations;
- transport and winding of coal, stone, materials, equipment and men;
- ventilation, methane drainage and air conditioning;
- main and district water drainage systems;
- measures to control sudden outbursts of coal and gas and rock bumps;
- construction of buildings and structures on the surface;
- wages, salaries, bonuses and allowances in kind;
- other operations and operations not taken into account.

Due to the fact that the objective function and the system of constraints are, as a rule, non-linear, the method of total evaluation and review of alternatives is used as a numerical method for computer-aided solution of the problem.

The above revealed methodology has been realized many times in particular planning of new and reconstructed mines in the main coal fields of the Soviet Union, and also in feasibility studies of layouts of opening and development of deep levels at the Donbass collieries. Application of the methodology allows within a short period of time for a considerable number (up to several thousands) of alternative options to be analysed and estimate costs for construction and specific operating costs to be reduced to 10 to 15 per cent (compared to traditional methods of planning) /2-4/.

The given methodology has been further expanded in developing automated coal mine planning systems. Such systems provide for standardization of calculation procedures and computer-aided formation of econometric models of projects of underground and opencast mines and coal preparation plants.

An automated coal mine planning system (SAPR- ugol) is being developed with the aim to improve the technical and economic level of planned enterprises, planners' productivity and the quality of project documents.

The above stated targets are achieved by introducing modern methods of optimization and decision-making, complex automation of planning operations and, on this basis, reformation of all kinds of planning provisioning /5/.

Thus economic effects of planning automation are revealed at mine planning, construction and operation stages (fig.3).

The SAPR-ugol system is being developed as on coal industry-wide, expanding, organizing and technical system of planning consisting of a complex of automation means for planning interrelated with divisions or sections of a planning organization.

The complex of automation means consists of the aggregate of methodical, programming, technical, informational and organizing provisioning. The SAPR-ugol functioning results in the aggregate of completed solutions and project documents presented in a given form. The coal industry-wide system SAPR-ugol is based on common (compulsory for use by all planning organizations and comissions of experts) methods of feasibility studies of project solutions, standards on planning and construction of coal mines, standard technology of automated planning. In the process of developing the SAPR-ugol system, a substantial portion of planning and calculation operations is computer-based by changing the contents and methodology of decision-making.

Evolution of the system is achieved by modular methodical and programming provisioning of the SAPR-ugol system which provides for actualization and expanding of the given types of provisioning, as well as operational changing and supplementing the data base of planning.

Organizing and technical basis of the SAPR-ugol system comprises standard (logic and information) models of the computer planning processes providing for the conversation (interactive) mode of operation (with optimum distribution of functions between the complex of technical means and the planner) and possible evaluation and control of decision quality in planning. Introduction of computer planning technology promotes improvements in organization structures and management control of planning organizations.

The main structural links of the SAPR-ugol system are standard object subsystems distinguished by functional indications: type of an enterprise (underground mines, open pits, coal preparation plants), planning stages (feasibility study, technical project, detailed project), element (object) of the enterprise under planning.

Object subsystems consist of functional and special parts (fig.4).

The functional part of the object subsystem is the aggregate of interactive, from information (programming) viewpoint, planning procedures realizing working out of project documents of predetermined quality and scope. Generally, the functioning part of the object subsystem is presented in the form of an information model of the planning process (fig.5), the apexes of which are planning procedures (F-formalized, N_g-non-formalized graphic, N_t-non-formalized connected with decision-making) and the arcs - input (output) for (from) these procedures information. The iterating nature of the planning process provides for reiterated return to previous procedures in case the planning results (solutions to the planning problem) do not satisfy, for some reasons, the planner. All procedures are strictly fixed according to information levels. Computer-aided planning provides for fulfilling a complex of procedures interactive from information viewpoint, (F - 1 + F - 6) either in the automated or automatic mode of operation when, by the planner's demand, the calculation process is interrupted in a "check point" (K_1, K_2) with input of information necessary for result analysis.

The Provisioning part consists of methodic programming, information, organization and personnel provisioning. In addition to provisioning object subsystems, common (for all object subsystems) components have been singled out - a complex of technical means; service of development; common elements of programming, information, organization and personnel provisioning.

Methodological provisioning components are documents stating the theory, methods and means for solving planning problems, mathematical models, algorythms, algorythmic (special) languages for describing objects, normals and standards. The SAPR-ugol system includes 59 object subsystems (including 9 subsystems which are invariant in relation to planning objects), the development of which requires reviewing and setting up a new library of econometric models of an enterprise and separate technological processes, methods and standards to computer technology of optimum planning.

Programming provisioning (software) presented, as a rule, by packages of applied programmes and technological lines of planning is based on the following principles:

- adaptability to the accepted computer configuration and computer operation circuit, as well as peripheral equipment;
- conversation made by operation;
- modular design;
- application of the permitted programming languages FORTRAN-IV and PZ-I;
- application of standard and serial software of coal industry-wide importance, in particular, for solving construction, heat engineering and other problems.

Information provisioning is based on maximum utilization of serial technical and programming means (data banks) and is constructed on the following principles:

- open structure adjusted to additional charge and merge;
- possible logic data structurization according to formal features;
- providing exactness of standard and normative data;
- delimit and protection of files and data blocks.

Organization provisioning is based on the following:

- type (logic and information) models of computer planning of separate objects and an enterprise as a whole;
- modern methods to evaluate and control the quality of planning solutions, standards and normative documents which regulate planning in the coal industry.

Technological provisioning is comprised of commercially available Soviet-made computers of third generation and peripheral equipment for intercourse between the planner and the computer (alphanumeric and graphical displays, graph plotters, coordinators, etc.). Automated work places for planners are being developed based on such devices.

The level and priority of developing the SAPR-ugol system are based on the analysis of technological and economic efficiency of planning operations automation (Э) and scientific and technological possibility of automation of such operations. In a general case, planning the level and priority of automation comes to a problem of linear programming with Boolean variables which is formulated in the following way /6/:

to find out $Э = \sum_t \sum_i \sum_j Э_{tij} X_{ij} \rightarrow max$, $i = 1,2,\ldots 20$; $i = 1,2,\ldots 58$; $j = 1,2,3$

with the following limitations:

1. $\sum_i \sum_t K_{tij} X_{ij} \leq K_j$
2. $\sum_t \sum_j A_{tij} X_{ij} \leq A_t$
3. $\sum_{j=1} \sum_i \gamma_i B_i X_{ij} \geq B_l$ $\qquad l = 1,2,3$
4. $X_{ij} = 0$ or 1
5. $\sum_j X_{ij} = 1$

where i - subsystem number; j - current queue number; t - number of year in the period under efficiency analysis; E_{tij} - economic efficiency of automation of planning operations fulfilled by i - subsystem in t-year if it is developed in j-stage, roubles;

$$X_{ij} \begin{cases} \text{-subsystem is developed in j-stage} \\ \text{- otherwise } = 0 \end{cases}$$

K_{tij} - capital costs for developing i-subsystem in t-year (if it is developed in j-stage), roubles;

K_j - marginal allocated costs for development assembly and introduction into semi-industrial and industrial operation of j-stage, roubles; A_{tij} - manpower expenditures for developing i-subsystem in t-year (if it is developed in j-stage), man-days; A_t - marginal allocated manpower expenditures for development, assembly and introduction into operation of the SAPR-ugol system in t-year, man-days; B_i - level of planning operations automation for i-subsystem determined as ratio of labour consumption (costs) for planning operations performed by the traditional method (without computers) to a similar index in computer-aided technology of planning; B_l - marginal level of planning operations automation in introducing the SAPR-ugol system in l-stage;

γ_i - specific labour consumption (costs) of planning operations performed by i-subsystem traditionally; l-stage number.

Criterion of evaluating the efficiency of planning operations automation is accepted as an index of aggregate economic efficiency (E_{tij}) taking into account efficiency in the sphere of planning (achieved by improving planner's productivity) and subsequent efficiency of optimum decision-making.

According to this criterion priority is given to such SAPR-ugol subsystems the introduction of which in the nearest future will allow for considerable improvements in the quality of planning solutions and reduction of labour consumption for planning operations.

Conclusion

The experience gained in the development and introduction of automated coal mine planning systems in the USSR shows that:

- development and introduction of automated planning systems in the main trend in the field of improving planning and estimated quality and efficiency;
- with the level of planning operations automation of up to 30 per cent and the expected expansion of planning operations scope in the coal industry by 50 to 60 per cent by 1990, number of planning organizations run by the Ministry of Coal Industry of the USSR may be practically kept at the 1980 level;
- in introducing methods of multiple-choice alternative planning and quality control of planning solutions, capital and operating costs may be reduced by 10 to 15 per cent. The reality of these figures is proved by the experience accumulated in the coal industry on automation of construction, technological and cost estimating calculations (the level of automation of which reached 40 to 80 per cent), as well as results of introducing more than 300 programmes and 20 packages of applied programmes. These programmes and packages provide for automated calculations of roof supports, methane drainage and air conditioning systems at coal mines, underground transport systems and winding installations, concrete and steel headframes, electric circuits, qualitative and quantitative indices of technological layouts and water-slurry circuits of coal preparation plants, mining and technical parameters and schedules of open-cast mining operations, etc.;
- formation of standard methodological provisioning of the USSR system requires standardization of composition and contents of all stages of planning, progect sections, elements of drainage and normative basis of planning. The efficient development of such provisioning is based on bilateral and multilateral cooperation with the CMEA member-countries;
- availability of considerable number (up to 30 per cent) of loan-components in the SAPR-ugol system provides for interdepartmental coordination of efforts aimed at developing special and common software for automated construction project planning systems (SAPR-OS), multi-purpose data banks SAPR-OS and the calculation control system as an integral part of computer operation systems;
- on the basis of the SAPR systems under development and in accordance with the plans for development and comissioning of such systems, it is necessary to improve the system of education and training of qualified specialists - designers and users of the SAPR systems.

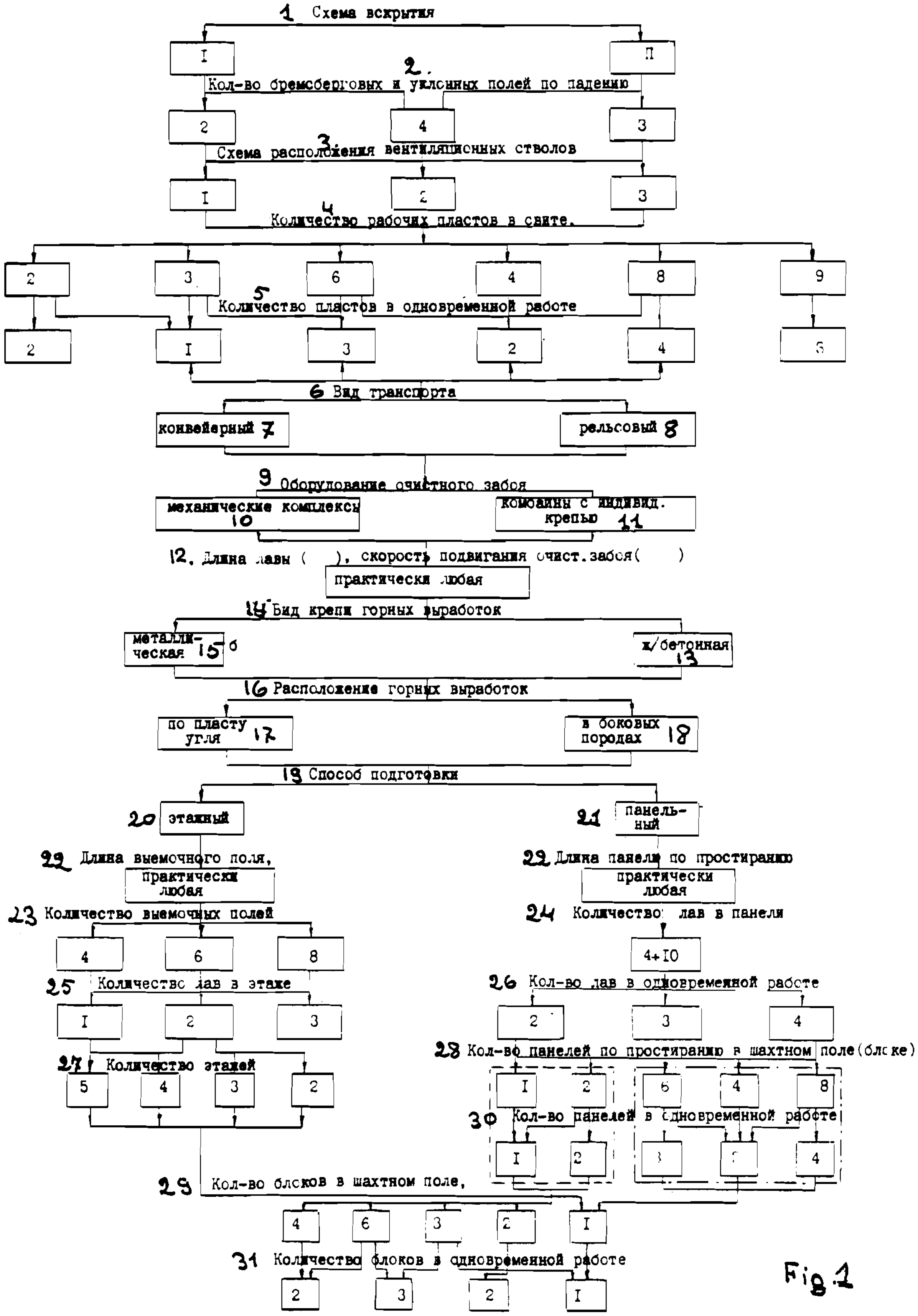
1 Схема вскрытия
I
П
2. Кол-во бремсберговых и уклонных полей по падению
2
4
3
3 Схема расположения вентиляционных стволов
I
2
3
4 Количество рабочих пластов в свите.
2
3
6
4
8
9
5 Количество пластов в одновременной работе
2
I
3
2
4
5
6 Вид транспорта
конвейерный 7
рельсовый 8
9 Оборудование очистного забоя
механические комплексы 10
комбайны с индивид. крепью 11
12. Длина лавы ( ), скорость подвигания очист.забоя( )
практически любая
14 Вид крепи горных выработок
металлическая 15
б
ж/бетонная 13
16 Расположение горных выработок
по пласту угля 17
в боковых породах 18
19 Способ подготовки
20 этажный
21 панельный
22 Длина выемочного поля,
практически любая
22 Длина панели по простиранию
практически любая
23 Количество выемочных полей
4
6
8
24 Количество лав в панели
4+I0
25 Количество лав в этаже
I
2
3
26 Кол-во лав в одновременной работе
2
3
4
27 Количество этажей
5
4
3
2
28 Кол-во панелей по простиранию в шахтном поле(блоке)
I
2
6
4
8
30 Кол-во панелей в одновременной работе
I
2
3
2
4
29 Кол-во блоков в шахтном поле,
4
6
3
2
I
31 Количество блоков в одновременной работе
2
3
2
I

Fig 1

English Translation of Figure 1.

1. deposit open schedule
2. quantity of the panels in the strike and slope
3. schedule shafts rentilation
4. quantity of the profitable seams in the sheat
5. quantity of the simultaneously working seams in the sheat
6. type of the transportation / haulage/
7. conveyors
8. railway
9. face equipment
10. powered supports,chain - type face conveyor, shearer - loader
11. seperate supports chain type face conveyor,shearer - loader
12. face length and advance / uresticted/
13. type of the gangway support
14. concrete
15. metal
16. scheme of the panel gang - ways
17. coal gangways
18. rock gangwys
19. way of panelling
20. stage - floor
21. panelling
22. panel length/ uresticed / 22a strike panel length
23. quantity of the panels
24. quantity of the face in the panel
25. quantity of the face in the stage-floor
26. quantity of the simultaneously working faces
27. quantity of the stage-floors
28. quantity of the strike panels in the block
29. quantity of the block in the panel
30. guantity of the simultaneously mining panels

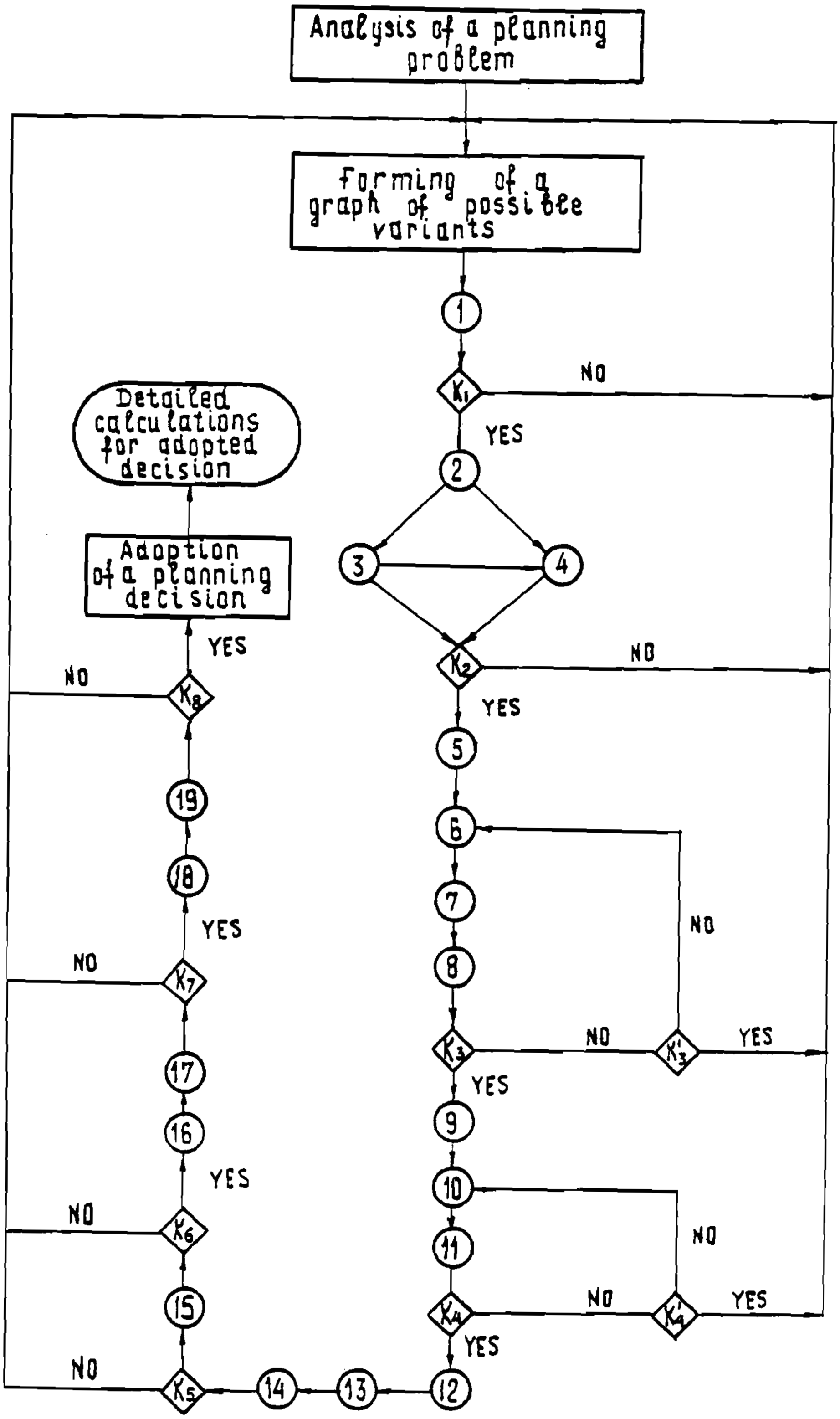
Analysis of a planning problem
Forming of a graph of possible variants
1
K1
NO
YES
2
3
4
K2
NO
YES
5
6
7
8
NO
K3
NO
K'3
YES
YES
9
10
11
NO
K4
NO
K'4
YES
YES
12
13
14
K5
NO
15
K6
NO
YES
16
17
K7
NO
YES
18
19
K8
NO
YES
Adoption of a planning decision
Detailed calculations for adopted decision

Fig. 2

Направления формирования экономического эффекта при внедрении САПР-уголь

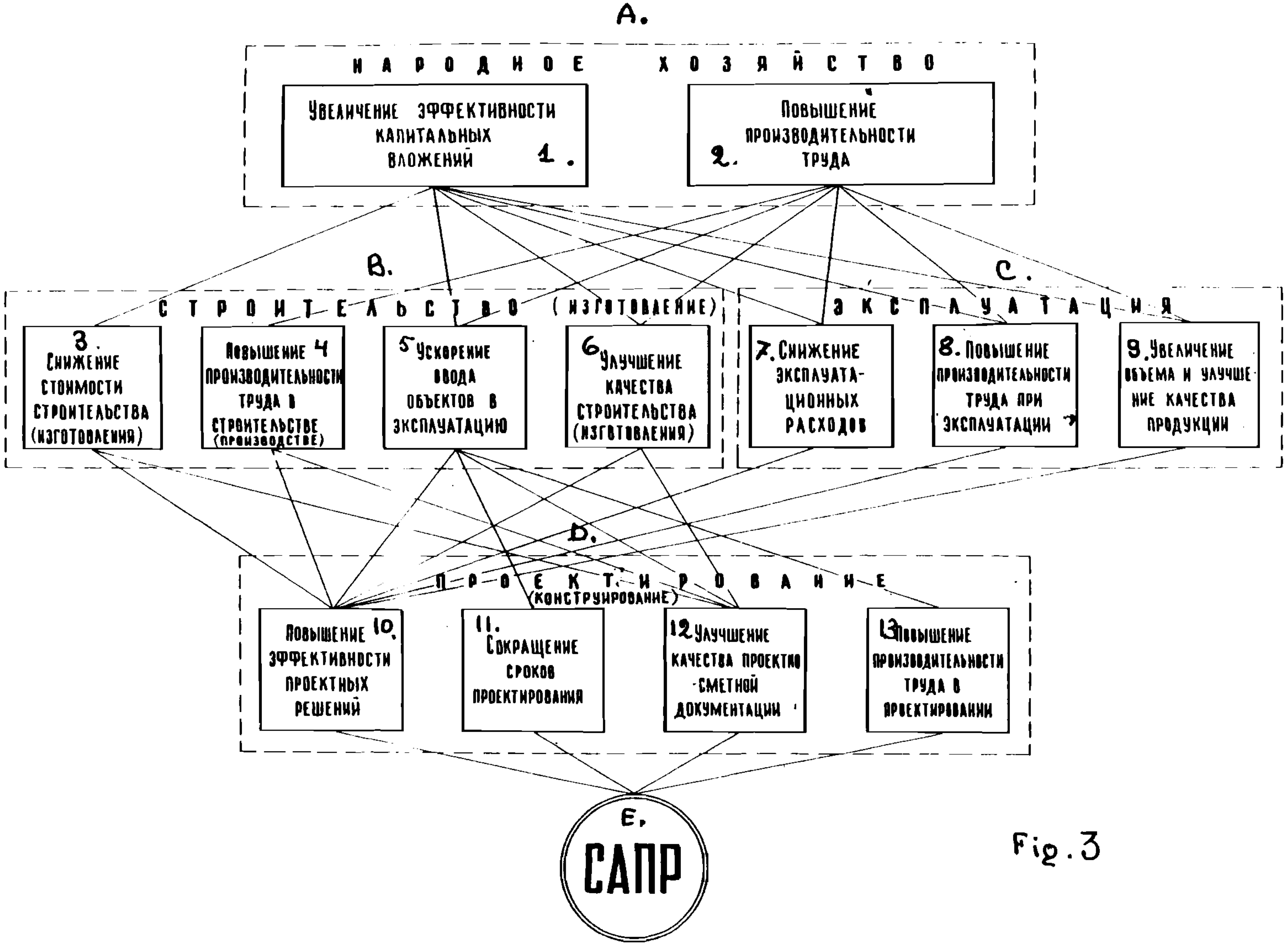

Fig.3

English Translation of Figure 3

Directions of formulating the economic effects while implementing SAPR - coal.

A. national economy

1. increase of capital investment effectivity
2. increase of labour productivity

B. Construction activity

3. reduction of the constraction cost
4. increase of the labour productivity in construction activity
5. acceleration of take new objects commissioning
6. improvement of construction processes quality

C. Maintence

7. reduction of the maintance expenditure
8. increase of labour productivity of the production processes
9. enlargement and quality increase of the production volume

D. Design activity

10. improvement of design effects
11. reduction of the design term
12. Improvement of the working plans quality and finance planning
13. increase of labour productivity in design processes

E. SAPR

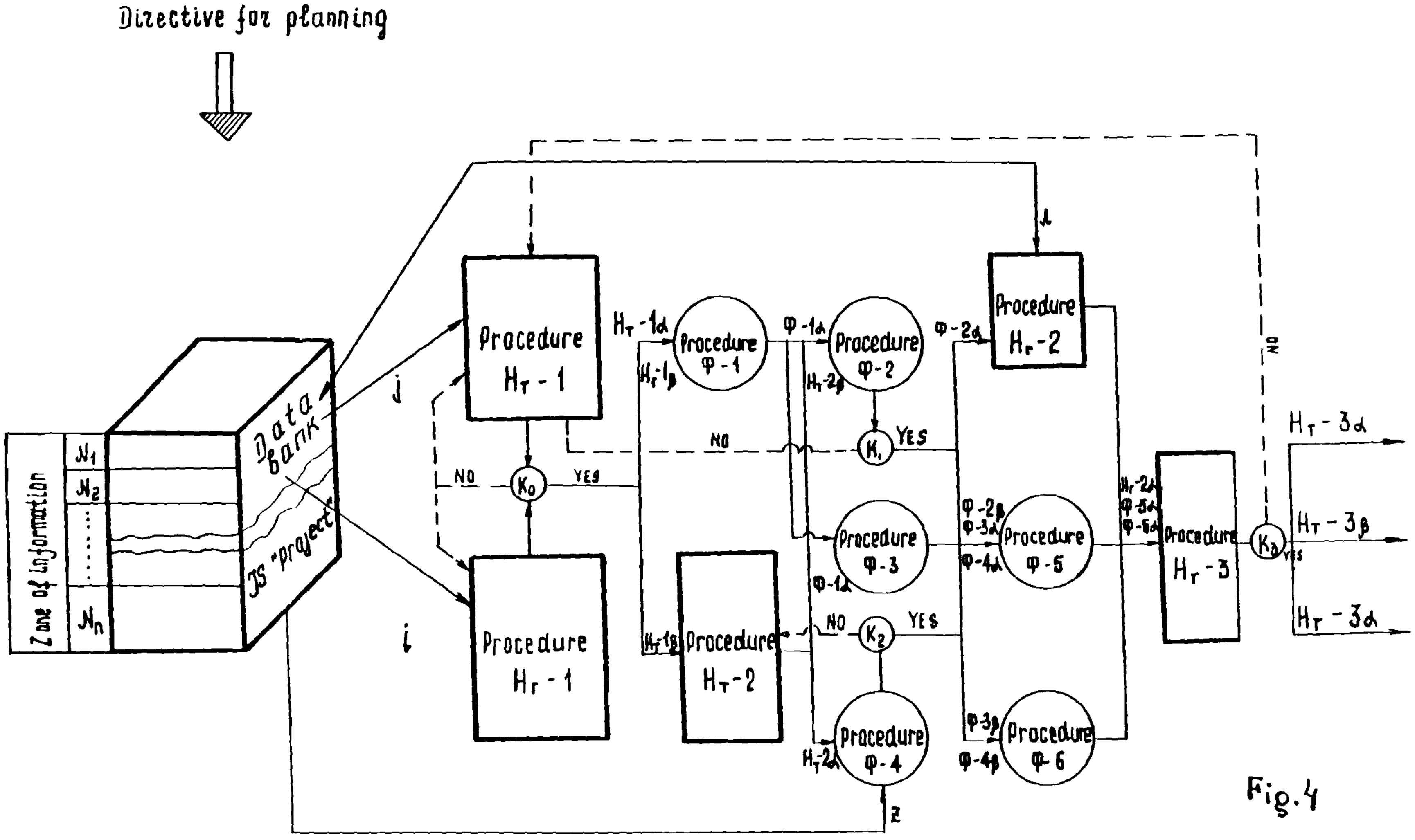
Directive for planning
Zone of information
N_1
N_2
N_n
Data bank
JS "project"
j
i
Procedure H_T - 1
Procedure H_r - 1
K_0
NO
YES
H_T-1α
H_r-1β
H_r-1β
Procedure φ-1
Procedure H_T-2
NO
φ-1α
H_r-2β
φ-1λ
Procedure φ-2
Procedure φ-3
Procedure φ-4
H_T-2λ
z
K_1
YES
NO
K_2
YES
φ-2α
λ
Procedure H_r-2
φ-2β
φ-3α
φ-4λ
Procedure φ-5
φ-3β
φ-4β
Procedure φ-6
H_r-2λ
φ-5α
φ-6α
Procedure H_r-3
K_3
YES
NO
H_T - 3α
H_T - 3β
H_T - 3α

Fig.4

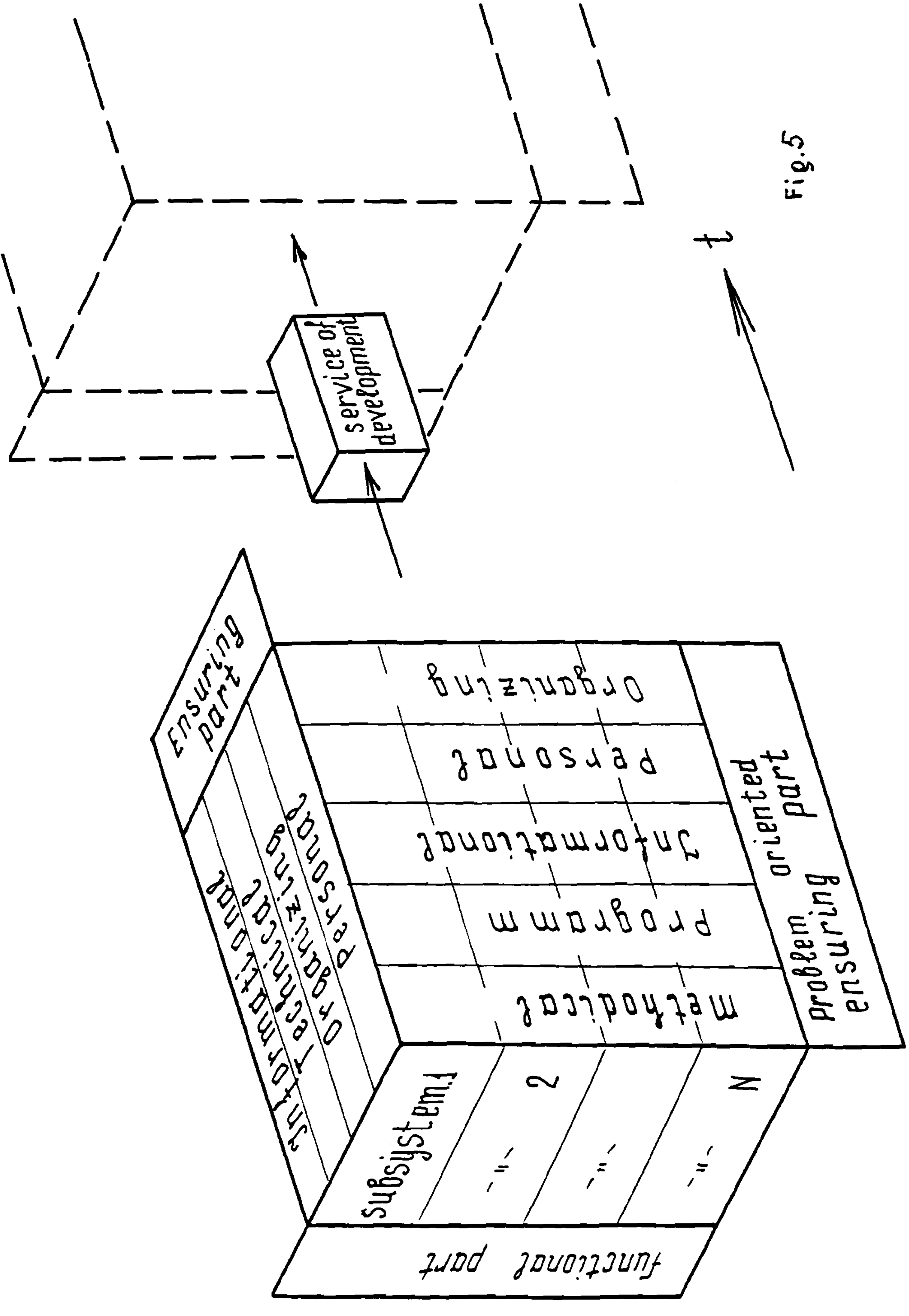
service of development
t
Ensuring part
Informational
Technical
Organizing
Personal
methodical
program
Informational
personal
Organizing
problem oriented ensuring part
Subsystem 1
-"- 2
-"-
-"- N
functional part

Fig.5

METHODICAL ELABORATION OF THE PROBLEM "DECISION MAKING MODELS OF THE FEEBLE STRUCTURED PROBLEMS IN THE COAL INDUSTRY"

V.V. Rogozov
S.A. Sorokin

I. Common propositions

Planning improving problem is one of the actual problems in the national economy. One of the possible directions of the planning improvement is represented by the application of the computers in the planning process. This direction is being implemented within the programme of the creation of the Automated Management Systems (AMS).

The extensive programme concerning the use of the "economico-mathematical" methods in the factory production planning is implemented in the coal industry. In the process of the implementation of such programme several different approaches were tested.

The first approach is a direct planning computation which received wide development and still undergoing the development process. Under this approach only the time needed for calculation is essentially shortened but the principal problems of the planning are not touched and that is the main defect of the first approach.

The second approach is the optimizational plan computations. The optimum planning is essential step in the planning methodology. The development and realization of the second approach was quite expensive in labour but it did't effect much the planning practice. This refers especially to the practice of the current (yearly) planning. The main reasons for such situation will be pointed out in the process of the justification of the third approach to the problem of the improvement of the plan computations.

The third approach is based on the use of the computers to control the process of the branch yearly planning with the help of the simulational method of the plannig. Such aproach was developed as a result of the experience of the planning problems computerization. The reasons for the "nonimplementation" of the optimum models are still under discussion. One of the main opinions of the failure reason is the absence of the accurate initial information. But the problem, in fact, is more complicated. It is well known that even the perfect system of "the Technico-Economical" Characteristics (TEC) provides only the generalised representation of the real situation on the production factory.

Such generalization as a means of selecting of the main, concentration of the essential is the principal property of the TEC system and therefore it posses less diversity then it is necessary for the adequate reflecting the productions situations. That is one of the main reasons for the information indeterminacy.

Besides the planning process always involves the future and that also increases the information indeterminacy. The information indeterminacy is revealed, in particular, in the fact that different persons involved in the planning process could be differently informed on the production resourses and such situation causes definite contradictions among different management levels.

Under the condition of the information indeterminacy it was quite natural to use the iterational way of obtaining the plan solutions which can be represented as a process of the consecutive constructing of the production target for the forthcoming period of time. In major cases it is impossible to formulate, in advance, the criterion system, stipulated for the plan. Such criterion system could be revealed under favourable conditions only after the planning process. The last stipulation is completely nonacceptable for the "chrestomathy" ideology of the optimum planning since it is necessary to declare the target part of the model a priori.

From the system analysis view the plan elaboration as well as the elaboration of any other problem of that kind which are to be solved under indeterminacy conditions and haven't got the accurate expressed criterion should be considered as a feeble structured problem. In the process of the solving of the feeble structured problems the content analysis methods of information processing are playing the role of the great importance but it should be remembered that the computational results obtained can not be absolutised. They can, as a rule, only be considered as an approximate estimates of the real situation. Under such conditions the level of the authenticity of the initial data in the planning system is mainly determined by the achieved degree of the structirization of the problem of the plan solution elaboration.

To avoid somehow the problems connected with the feeble structurization of the problem in the automated management systems the Person Making the final Decision (PMD) is included in the AMS. Then as the main regime of the AMS system functioning is the "man-computer" dialoque regime choosen.

But under such stipulation the following question may be aresed: whether one person can be qualified enough to direct the plan elaboration including the wide range of the TEC. Thus we are arriving to the idea of the personified model of the mutual connections of the TEC for each PMD from the planning department. To make the organization of the planning computational job effective it is necessary to assume that the rights and obligations of the PMD, using the model, allow him to make decisions within the limits of the characteristic list, involved in the considered model; the competence of the PMD permits him to enter to computer considerations, deduced with the help of the content analysis, which supplement the model and which are, to his opinion, necessary to be entered.

As a complete the automated management system should be composed as a union of the models and for each person responsible it is necessary to elaborate the personified model. The hierarchical system of the personified models should reflect the administrative as well as the procedural hierarchy of the planning aparatus. One more aspect of the feeble structurization is revealed in the peculiarity of the computerised simulation where the key problem is the way of the information indeterminacy fixation. Under such approach the numerical value of each characteristic is ought to be given in the form of the intervals of possible values. Such system of intervals,which are all compatible in a certain way,could be interpreted as a domain of permissible plan values over the characteristic group.

For the hierarchical system of the TEC models as a whole the similar problem arises, i.e. the problem of the obtaining the common plan solution domain,composed from the separate domains connected with the TEC models. This problem is reduced to the problem of consistency of the plan solutions within the range of the complete hierarchy. But here again one more question of the principal importance arises: to what extent of the accurasy and correctness the procedure of the plan solution adjusting could be realized under conditions of the feeble structurization?

At the present stage the branch plans are represented in the form of the set of the plan characteristic values, i.e. the plan solution domain degenerates into the point. The representation of the plan in the form of the certain (nongenerated as a rule) domain of the plan solutions appears to be more correct and sound. Under such representation each characteristic is given in the form of the interval of permissible values. Then different planes are adjusted to an accuracy of the certain system of the intervals, i.e. to that degree of an accuracy which is being reached in the process of the indeterminacy reduction in the course of the planning. The traditional practice of the planning disposes the number of the approved methods of the TEC calculations. Such method is constructed in a manner that it composes the object of the job for the certain plan officer over the range of the problems considered as well as the means of their computation. Moreover, the set of these methods represents the certain ideology type of the traditional branch planning, certain system of thought of the people involved in the planning job. That is why the transition to the new system of the methodic guiding principles is a complicated process, conjugated, in essence, with the introducing the thought system as well as the completely different job ideology.

The last point is often ignored, e.g in the process of the transition of the plan calculations to the computarization. Computarizion of the traditional approved methods of the TEC calculations performed before manually is proved to be little effective. To increase the efficiency of the planning the computers are used to realize the modified methods based on the modern theory of the mathematical programming, theory of the games and etc. Such situation causes not only the change of the tooling but demands to introduce the different ideology of the planning job, different sort of the skill and and the working style of the planning department and that is not possible to change it at once. That is one of the possible reasons which explains the diffuculties emerged in the implementation process of the optimizational planning methods.

The combination of the revolutionary change in the tooling (for instance, transition from the mannual calculators to the computers) along with the evolutionary change over from the existing to the new, refined and regulating the branch planning economical methods appears to be more reasonable. In the sufficient measure, such way is satisfied by choosing of the two relatively independent directions of the development of the automized system of the current planning.

Firstly, the elaboration of the hierarchical system of of the personified models of the mutual connections of the TEC (TEC models). Each TEC model is based on the one or several approved in the planning practice methods of the TEC calculations.

Secondly, the elaboration of the special software of the certain operaional system orientated to the planning computations and satisfying to the following conditions:

-the system must be invariant in the respect to the any of the TEC models, included in the planning process;

-each TEC model for the operational system must be not only the supplier but also the source of the directing information;

- the output of the operational system should be interpreted on the lanquage of the characteristic list, included in the certain serviced TEC model.

The orientation of the independent labour in two different directions: hierarchical TEC model systems (model of the planning object) and operational system of the plan computations (planning process model) is also effective in the part of the distrubution of the labour efforts. The elaboration of the more perfect economical methods and based on them TEC models is appropriate to assign to the people of the following specialities: economy, the mining production engineer. The elaboration of the operational system of the plan computations is the responsibility of the mathematicians and datamation specialists.

Under such approach the functioning of the automated system of the current planning would be carried out in the following way. Each MDP from the planning department is working directly with his own TEC model, corresponding to his rights and obligations and " unnoticably " supported by the the operational system of the plan computations. Operational system, significantly widening the computation possibilities,holds the quantitive side of the planning process, interpreting the computational results on the TEC lanquage,holding all the relations among the characteristics provided by the model.

For more detailed discussion of the raised questions it is appropriate to consider each of the directions separately.

II. Hierarchical system of the personified TEC model

Under the model of the interrelation of the technico-economical characteristics is being understood TEC with the defined on them relations of the given proporties.

The personification principle, i.e. orientation on the definite person from the branch planning department allows to define both the TEC set and "the relations of the given proporties". In other words, it is possible to introduce certain economical method as a quidance to the concrete plan officcer to compute some characteristics through the others.

Thus the personification principle allows to define the main structural characteristics of the TEC models. But the definition of the functional characteristic is far more complex problem. The most important conditions under which the branch yearly planning process proceeds were stated earlier.

That is the information indeterminacy, vaque formulated criteria system, certain contradictions arising among different management levels and etc..

Such conditions put the problem of the current production plan elaboration into the class of the feeble structered prolem with all the consequences following.

Personification principle and the conclusion made upon the feeble structurization of the current plan task elaboration problem provides practically the unique selection of the main regime of the function of the automated system of the plan computations - "man - computer" dialoque regime. Such dialoque is mainly based on the TEC model which determines the communication language of the man to computer and vice versa, determines also the class of the problems to be solved and determines information supply to the concrete person responsible.

Efficiency of the functioning of the automated planning system as a whole mostly depends on the dialoque efficiency. In its turn, the dialoque efficiency is determined by the motivation of the Decision Making Person (DMP), the one, who makes use of the TEC model at his job. In other words, the functional characteristics of the models should be introduced in a such way which would attract the DMP to make use of the TEC model.

It is quite natural to make the following assumption: the DMP would be interested in making use of the model provided he can obtain from the model use the results which can not be obtained without use of the model or if they are obtainable without use of the model then at the high labour cost. But while exposing the personification principle of the TEC model the following conclusion was made: any TEC model should be based on the certain approved guidance of the TEC computation, corresponding to the rights and resposibilities of the appropriate person in charge from the management department.

Under such conditions the new results obtained with the help of the corresponding model must be observed in connection with the approved methodology, their interpretation should be done by using " the language " of that method and they should, in a certain sence, " inrich " the standard method of the characteristics computization. In other words, each TEC model should"tie up in one knot" all the questions concerning the normative guidance of the corresponding DMP while planning, should " light it up " from the different points of view, should expose different sides of the plan solution elaboration, should " fill " the substance into the formality of the normative method. These quantitive reasons are taken into certain consideration provided that some sort of the principle of the complementarity is being followed in the process of the TEC model elaboration. The overall integrative representation of the certain object can be obtained by means of constructing the set of its different describtions, proceeding each time from different or even from opposite initial premises.

The"man - computer " dialoque regime can be considered , above all, as a certain illustration of the complementarity principle. From one point of view, each TEC model appears as a purely formal outset in the system as a whole. On the other hand the, bearer of the nonformal source in the whole system appears to be the DMP, the one who can enter into the model additional information of the heuristic character, reflecting his experience,intuition, skill, motives. If the important problem of motivation is to be concidered from the position of the complementarity principle in more details then the TEC model structure can be revealed far more detailed. It is quite resonable to assume that the DMP would be motivated and gets some additional information in the following cases:

- each computation,in accordance with the standard method assigned by the DMP,would be followed in the model by means of the checking of the feasibility of some restricting conditions;
- each standard (normative) computation would be followed additionaly by the sequence of analitic computations thus exposing the possible variations of the standard computation;
- other different versions of additional accompaning plan solution computations.

In essence, the general structure of the TEC model emerges to be as follows. Each TEC model should contain some basic structure unit which is to be used to compute the normatives, the set of the additional structure units, responsible for the certain computations,completeing normative calculations with the different type of the analyses, optimizational computation variants, computation of the forecasting character and etc..

If such structure is being considered from the system analyses view then , as the matter of fact, the TEC model represents itself the composition of some decision making countours of the control. Here the main structure represents direct process and the set of the completing structure units are the feedback processes.

The plurality of the feedback processes in the the model exposes the feeble structurization of the plan solution elaborating problems. Here the feedback control exposes itself in the following - the feddback can only " advice "in which direction the target could be reached and it is not known, in advance, which of the feedbacks leads to the solution required.

From the formal view, the planning process can be considered as a process of the sequeintal reduction of the indeterminacy. The mechanism of this indeterminacy reduction process exposes itself in the following.

The first computation based on the standard methods gives the interval of the permissible values of output (being planned) technico-economical characteristic (or characteristic set). Each following computation conducted with the use of the additional model fragments can bring in certain correction of this interval of the considered output TEC (or TEC set). Such correction exposes in the narrowing the interval, i.e. the indeterminacy reduction. If the ideterminacy reduction does not occur, then the computation on such complementary fragment is proved to be the noninformative one. The sequence of such kind computations can provide quite acceptable information indeterminacy level (the information inteterminacy reduction has always got its limit which is not equal to zero).

Thus, the TEC model should represent certain controlled aggregate with the purpose of the obtaining and refining the quantitive characteristics of the plan solutions, where the model structure appears to be the control parameter. Before we start discussion of the TEC model hierarchy problem we introduce a few definitions.

Two TEC models are called connected models on the base of the common characteristic if in either of the models is being used at least one common technico-economical characteristic.

The TEC model hierachy is the set of the TEC models distributed over the TEC personified model control levels, where only the connections among the models, situated at different levels, are taken into consideration.

The coordinator model is the TEC model, connected with the severel models of the below situated levels on the base of the common characteristic principle.

The executor model is the TEC model, subordinated to the certain (single) coordinator model situated at the level above. In accordence with the last definitions, hierarchical system of the TEC model could be considered as certain compocition of the coupled models, i.e. coordinator - executor models.

The main purpose of the elaboration of the hierachical model system is to reflect to its possible full extent the formal (computational) part of the planning process. In this connection the following request is quite rightfull:

the personified hierarchical TEC model system should be elaborated and organised in a such way that it should, in a certain way, reflect the administrative structural hierarchy of the planning apparatus. Under such statement of the matter the problem of the improving of the branch plan service structure could be, with the high degree of an accuracy, identified with the problem of the improving of the hierarchical TEC model system, provided there exists develöped enough hierarchical TEC model system.

As a whole the functioning of the hierarchical TEC model system is suitable to represent with the help of the two model procedures " Task Distribution " and " Perfomance Rating "

Model procedure TD (Task Distribution) is the standard procedure which allows the solution , elaborated on the base of the coordinator model, to be reduced to the subordinate executor models.

The model procedure PR ("Performance Rating") is the typical procedure, allowing to estimate decisions elaborated on the performance models within the limits of the coordinator models.

The planning process based on such model procedures provided there exists the developed enough hierarchical TEC model system could imagined in the following way. The person, responsible for the preparation of the certain planning decision (the coordinator, responsible for the solution of the common planning problem as a whole at the concrete management level), is working out the concrete expression of such decision at the TEC language and with the help of the TD procedure distributes the task over to the subordinated performance models, i.e. to the corresponding persons. Those executors, who received their tasks could play, in its turn, the coordinator role in solving of the appropriate part of the problem as a whole. In this case , the procedure TD is being repeated on the whole integrity of the subproblem set. Thus, the TD procedure could be moved down along the hierarchy untill the complete range of the persons involved in the planning solution would be incircled.

When the "last" executors involved receive their task they, on the base of their models , are able to estimate their resources to implement the solution with the concretization of the values of the appropriate TEC list and, possibly, could make certain proposals, observations and amendments of the task received. Then the reverse P_R procedure starts to operate. The reverse P_R procedure moves up the worked out results of the corresponding TEC models (estimates, observations, amendments and etc.). Finally, the corresponding information returns to the person who initiated the TD procedure on the considered plan solution. Eventually, it is quite possible to organize the multiiterational passage from the top down to the bottom as well as the passage between the intermidiate coordinators and executors.

The final result of the one or several iterations represents itself the model " realization " of the plan solution being prepared. As a result of such process the person, initiated the model simulation of the action, obtain the result reflecting all the management chains involved in this action.

The scheme, proposed above, provides the representation of the planning simulation process being elaborated. At the same time the final elaboration aim is being defined which is to design the hierarchical TEC model system, providing the " overlapping " of the management department structure as a whole.

III. The operational system of plan computations

THE OPERATIONAL SYSTEM of PLAN COMPUTATIONS is the organised collection of the programs which provides the possibility to computerize the simulation of the planning process. Here the concrete TEC model appears to be each time as the bearer of the initial data for the computations as well as the source of the controlling information. The purpose of the OPERATIONAL SYSTEM of the PLAN COMPUTATIONS (OSPC) is " to accompany " the planning process, i.e. the process of solving of the feeble structured problems. The success and the eficiency of this " accompaniment" depends greatly upon the distribution of the functions beetwen OSPC and hierarchical TEC model system. Eventually, OSPC should perform all the necessary formalised computations and should also provide the maximaly wide possibilities of the " entering " into system with the minimum restrictions.

The real premise of the accent shifting to the solving of the qualitive problems in the system is the selection as the basic OSPC functioning regime - the " man - computer " dialoque regime. The last is fairly well agreed with the orientation of the TEC model personification. To provide the realization of the raised aims OSPC should include the wide enough selection of the problem solving algorithms which can emerge in the process of working with this or that TEC model.

And once again about the interrelation between certain TEC model and OSPC. TEC model is presented by the system of equations, decribing the interrelation of the certain TEC group and it (TEC model) does not require special organisation with the aim of the application of the certain mathematical methods, e.g. mathematical programming, mathematical statatics, theory of the games and etc.. All these functions are fulfilled by the OSPC. The OSPC, on the base of the concrete TEC model, selects the appropriate problem depending on the information available, DMP requests and computational stages. Further, the solution of the problem obligatorally (that is one of the basic requirements) stated on the language of the TEC group which forms the base of the model being servised. Such approach somehow reduces the diffuculties arised while making use of the fine mathematical methods in the real planning practice. Thus the " unnoticable " backing provided by the OSPC of the TEC model functioning opens wide possibilities of the utilization of the wide " arsenal " of the refined mathematical methods without any need to introduce them to the DMP. The difficulties on this path are the the problems arised in the process of the OSPC creation. But they are of the different nature then the difficulties, connected with studying of the modern mathematical methods by the members of the traditional plan service.

But the set of the algorithms does not provide itself the system itself as such, in a common sence. To turn the set of the algorithms into the system it is necessary to introduce certain system forming idea, certain " rod " of the constructing the system as a whole. In the OSPC such system forming idea is represented by the procedure of the adjusting of the plan solution. The selection of that kind is justified, above all, by the following reasons:

- firstly, the adjusting procedure presents in any of the planning process;

secondly, the adjusting procedure allows the strict formal representation,

thirdly, the measure of the plan solution adjustment could be choosen as a measure of the TEC model informative providence as well as the measure of the information supply to the DMP, making use of these models.

Now when the main part is being clarified, i.e. the introduction of the adjusting procedure as a basic system forming formal outset of the operational system, we are in a position to consider the sequence of the complementary principal propositions, which would allow to clarify other aspects of the constructing and functioning of the OSPC.

Let us consider, first of all, the problem of the further development of the principle of the complementarity. The functioning of the OSPC should be arranged in a such way that the certain balance should take place,mutual complementarity of the formal and nonformal outsets. Obviosly, " the shift " in this dynamic balance should be " aligned " by the system and the most effective final plan solution could be obtained under equilibrium, mutually complementary state of the formal and nonformal outsets.

One more version of the complementarity principle is being used in the interior organization of the operational computation. Indeterminacy of the information being used to obtain the single-valued solution is re-established by the interior common criteria of the following types: selection of the most stable solution (stable relatively to the concrete TEC model and information available at the present moment), selection of the solution with the least conditional strain. Let us introduce one more impotant proposition about the principle of embending.

If the OSPC funotioning is imagened as stage by stage reduction of the TEC permissible values domain, then the domain, worked out at the next stage of the OSPC functioning, must be embeded relatively to the domain of the permissible values, worked out at the previous stage. In the contrary case, it is necessary to come back to the previous stages of the OSPC job. The sequential observance of this principle is the necessary condition of the obtaining of the adjusted plan solutions over the whole hierarchy of the TEC models.

Now we are in a position to represent the the automated planning process from the OSPC point of wiew. The operational plan computations system should be composed out of several packets of programs with different task assignments.

The packet of programs, call it " Estimate Computations ", should perform the prelimenary job. The aim at this stage is to obtain the Estimate intervals of the Permissible Values (PVE) over the concrete TEC.

The number of the TEC which require the estimate computations depends on the sequence of the conditions:

the extent of the development of the TEC model hierarchy;

- the possibility to obtain several independent estimates for one and the same characteristic (with the aim of the increase of the reliability);

- the extent of detailization required of the plan solutions being elaborated.

As a result of the estimate computations for each TEC model the PVE can be obtained for the all being planned TEC. These computations are performed in a such way that their results could be interpreted as a rough stage of adjusting (coordinating) of the planning process. Here it is being assumed that in this case the begining of the adjusting process is represented by the production process itself and which is being estimated by the method of interval estimates of the corresponding TEC. Under this condition, the PVE obtained could be nonjusted, i.e. some of the equations of the TEC mutual connections could not be satisfied in this domain. The extent of nonjustment of the PVE is one of the main characteristcs of the performance quality of the packet " Estimate Computations ". The next program packet of the OSPC (call it, in brief, " Domain ") is aimed to obtain the adjusted Domain of the Plan Solutions (PSD). At this stage more sensitive adjusting procedures start to operate. The basic exploitational regime of the packet " Domain " should be the " man - computer " dialoque regime, i.e. the main input information is represented by the complementary information, supplied by the DMP.

At this stage the DMP aims are to clarify the production resourses, which on the TEC language are represented by the domain of the permissible values. Naturally,that part of the PVE is of the utmost interest which reflects the utmost probable and stable values of the considered TEC. In this connection the automated planning process is constructed according to the following scheme: the DMP brings in his opinion about the most stable part of the PVE and then the computer, on the base of this information, " attemts " to construct the domain of TEC values, adjusting it with the retrospective information available, with the results of the possible complementary analyses and checking of the restricting conditions and with the opinions of the other participants of the planning process.

The model procedures " Task Distribution " and " Performance Rating ", introduced above, would be expressed on the language of the program packet " Domain " as follows. In the process of the plan solutions elaboration on the base of his model over the characteristics, connecting it with the corresponding models of the executors , the intervals are obtained, which are, in its turn, in the form of the task passed on the corresponding models of the executors. That is what the task distribution means. Similarly, the reverse process is the process of the passing the corresponding intervals from the executor models to the coordinator model. At this stage the certain performance rating of the earlier given out task is being made. That is how the performance rating process works. It is worth to mention here, that the informative exchange on the base of the interval characteristic changes is potentially richer in variety compared to the exchange by the point-wise characteristic values. Similarly, the plan values domain posesses greater variety, i.e. it is potentially fuller able to " feel " and " to reflect " the state of the system, then traditional representation of the plan assignement in the form of certain vector of values over the definite TEC set.

The program packet " Domain " is aimed to simulate jobs, conducted in the process of the traditional yearly planning and, in general, corresponds to the investigation of the production resourses for the forthcoming plan period.

The next stage of the yearly planning, connected with the direct plan task assignement and distribution should be simulated by the program packet, called " Outcome ". The input information of the packet " Outcome " is represented by the OSPC, worked out by the packet " Domain ". Here again the main exploitational regime is the " man - computer " dialoque regime.

The purpose of the programm packet " Outcome " is to provide the DMP by the posibility to answer to the question of the type: " What happens if...? ". In other words, the aim of the " Outcome" packet is to simulate the outcomes of different possible production situations, worked out by the OSPC. Thus the " Outcome " packet is aimed for the analys and investigation of the elaborated plan solution domain by means of simulating different possible outcomes of the production activity. Such investigation of the PSD can clarify which production chain appears to be the most weak in the process of the simulation of the desirable outcome

(plan assignment). After that it is possible " to play over " the most rational resourses distribution components of the model with the aim of the providing the most reliable conditions of the fulfilling of the plan task.

Thus, the investigation of the PSD provides the possibility of the constant purposeful adjustment of the system, motivating the fulfillment of the new tasks in the constanly changing production conditions.

Conclusions

Realization of the approach discussed above appears to be promising.

I. Automation includes the wide range of the procedures from which the planning process is being composed, which, in its turn, includes (besides optimization) forecasting, analys, direct planning computations and etc..

2. Relatively independent elaboration of the planning improving problem in two directions (hierarchical TEC model system and operational plan computation system)by specialization and concentration of the efforts of the designers at the elaboration stage, by the suitable separation of the function between the hierarchy of the TEC model and operational system of plan computations at the stage of the simulation of the planning process.

3. Hierarchical system of the TEC models is constructed in a such way that it should structuraly be directed to the consequitive reduction of the informative indeterminacy.

4. As a system forming principle of the OSPC is the multitask procedure of adjusting of the plan solutions choosen, which allows to combine and to use in the unified system different strick mathematical methods.

5. Many discussional questions of the planning improvement, including the question of interrelation of the plan and the additional task, the problem of the separation of the planning characteristics into approved and computational ones and etc..

Finally, the planning, based on the interval TEC characteristics provides reasonably good premises for the exposure of the self-training of the production systems while the traditional planning methods fairly often restrict the self-training outset of the factory.