SELECTED PROBLEMS AND RESEARCH METHODS OF THE POLISH MINING INDUSTRY RELEVANT TO THE IIASA COAL STUDY

J. Stachowicz, W. Łakomy, and
J. Bendowski

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INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

PREFACE

We will conduct investigations on problems connected with the design of organizations in the mining industry. This work could be treated as a case study for IIASA's program, Coal - Issues for the Eighties. But we must get other countries to deal with similar studies as well. It would be very fruitful if these studies were developed on the basis of common methods that could be worked out during our cooperation in this field at IIASA. It is hoped that this cooperation will give a common base for answering questions directly connected with Coal - Issues for the Eighties.

In this paper, we will describe our interest in working on these problems within IIASA's program.

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INTRODUCTION

Particular importance is given to mining research and design in the Polish economy. As a result, the Ministry of Mining was especially interested in IIASA's research dealing with the problems of world coal mining development. We expressed our interest in the IIASA work by helping the Management and Technology Area (MMT) with decisions concerning the design and purpose of the proposed research.

Because it was important that Mr. R. Tomlinson be familiar with the Polish mining industry, we scheduled working meetings for him with leaders of all levels of management, including the Ministry. This paper is geared toward Mr. Tomlinson's particular interests: research on management systems and computerization.

Mining specialists throughout the world recognize the achievements made by the Polisy mining industry. Particularly notable are the contributions of the Polish School of Designing, as it has come to be known, in the area of mine design. Other important advances have been made in work safety, rheology, prevention of rock burst, and especially in the development of a technique to extract coal from the support pillars that lie beneath housing developments and towns (about 50 percent of Poland's coal is currently obtained from these pillars). However, further research in several areas will be required to assure the planned development of our mining industry. Specifically, this involves research on technological and organizational progress, adapting to the varied geological conditions encountered in mining, and the economics of deposit exploitation using improved technologies.

The research and development (R&D) program of the Polish Mining Industry for the years 1976 to 1985 can be divided into six basic groups:

(1) Forecasting the growth of the mining industry in the next 25 years in light of both the increasing cost of coal extraction and increased energy needs.

(2) Development of guidelines for worker safety.

(3) Research into improved mining technology.

(4) Research into the problems of coal utilization.

(5) Environmental protection, particularly in connection with mine waste materials, secondary minerals, and mine water.

(6) Research dealing with management organization and mining economics.

Several of these problems relate directly to topics covered in the MMT coal study. This study recommends the use of an integrated, systems analysis approach to prepare for the problems which will arise due to increased coal demand. Based on our previous findings, particularly from research on the more utilitarian problems in coal mining, we fully support this view.

OVERVIEW OF THE POLISH MINING INDUSTRY

Poland's mining industry is comprised of 65 mines and employs about 380 thousand people. The mines can be grouped into seven "unions", or areas. Six of these unions, each containing ten mines, are located in the Lower Silesian Coal Basin.

Since the Second World War, coal output in Poland has risen steadily. From 1970 to 1977, production has increased from 140 million tons to 186 million tons, with an average annual increment of 6.6 million tons. More and more mines have a daily output exceeding 15 thousand tons. Several factors contribute to this steady increase in production. First of all, older mines, and even some of the newer ones, are in the process of being renovated. The reorganization of the older mines into larger, more efficient production has also produced favorable results. Finally, by increasing mechanization in the mining process, we have been able to increase the output of a single face considerably. For example, between 1970 and 1977 the average daily output from a longwall face with caving increased from 600 to 1000 tons per day; the output from a single production level rose from 2300 to 4000 tons a day during this same period. Ninety-five percent of the mining production process along faces, particularly longwall faces, can be mechanized. Today 60 percent of Poland's coal output comes from faces with mechanized support, with the number of mechanized faces increasing rapidly.

As Poland's coal production increased, and the easily-accessible coal mined, it became necessary to excavate under increasingly difficult mining conditions. The unfavorable mining

and geological conditions, and the increased risk involved, are reflected in these statistics for the period between 1970 and 1977:

-- The average excavation depth increased from 413 to 491 meters;

-- Output from depths greater than 700 meters rose from 3.7 percent to 15.8 percent;

-- Output from gassy seams increased from 40.7 percent to 48.9 percent;

-- Output from mines where the danger of rock burst exists rose from 38.8 percent to 51.8 percent; and

-- Output from support pillars increased from 40.6 percent to 54.9 percent.

Forecasts of coal production for the 1980's predict even further increases in output, although a corresponding increase in employment will be limited. In 1980, Poland should produce 210 million tons of coal; 240 million tons is predicted for 1985. It is anticipated that increasingly difficult-to-reach coal will have to be mined to achieve this increase, with the accompanying problems of air-conditioning, rock burst, etc.

The Polish coal industry receives support not only from the scientific and research community, but also from related service industries. For example, the mining machinery union, made up of about twenty factories, produces the modern mining equipment essential for increased coal production. Investment strategies for the entire coal industry are decided upon by specialized organizations within the mine construction union and the coal industry construction assembly union.

Thus, the coal industry is supported by an integrated system of specialized support services. As a result, the following centralized activities are performed for the whole industry:

-- coal sales,
-- mine timber supply,
-- exploitation and supply of stowing sand to the mines,
-- supply of other materials.

The following institutions contribute to research and design for the Polish mining industry:

-- The Central Mining Institute (GIG);

-- The Computer Institute of the Mining Industry (COIG);

-- The Chief Mining Studies and Design Office (GBSiPG);

-- The Research and Design Center for Minerals Processing and Utilization (SEPARATOR);

-- The Central Designing -- Technological Center for the Mining Machinery Industry, (ORTEM);

-- The Central Designing--Constructional Center for Mining (KOMAG);

-- The Research Center for Mining Constructions (OBRPW); and

-- The "BUDOKOP" Research Center. This institution helps solve problems connected with the design of new technologies, worker safety, and environmental protection.

According to what we said before, the problems connected with organizational and management aspects of the mining industry are of special interest to us. To accomplish the research dealing with management organization and mining economics we would like to utilize a methodological procedure for analyses that has been proposed in a background paper for the Coal Task Force Meeting. This is shown in Figure 1 by means of solid lines. For this purpose we propose an additional branch (signified by dashed lines in Figure 1) as a complement of this methodological procedure.

THE PURPOSE AND METHODS OF THE PROPOSED RESEARCH
(See Attachment 1, Proposed Research Topics)

Topic 1--Systems Approach to Mining Industry Development

Topic 1 deals with the theoretical and methodological aspects involved in planning the development of the mining industry. A special emphasis will be placed on the systems approach, which integrates scientific, technical and organizational development. Many of the assumptions of this approach have been developed at IIASA.

Section 1.1 deals with the methodology of modernizing and designing management systems in the mining industry.

Section 1.2 involves a study to determine the relationship between the size of the economic unit and its production effectiveness.

Background and Purpose of the Study

The following conditions will shape the future development of the mining industry:

-- the world economy will shape coal demand trends;

-- it will become necessary to integrate coal exploitation and utilization on a global scale;

-- mining and geological conditions will continue to worsen;

-- fewer people will be willing to work in coal mines;

-- there will be increased competition from other raw materials (fuels);

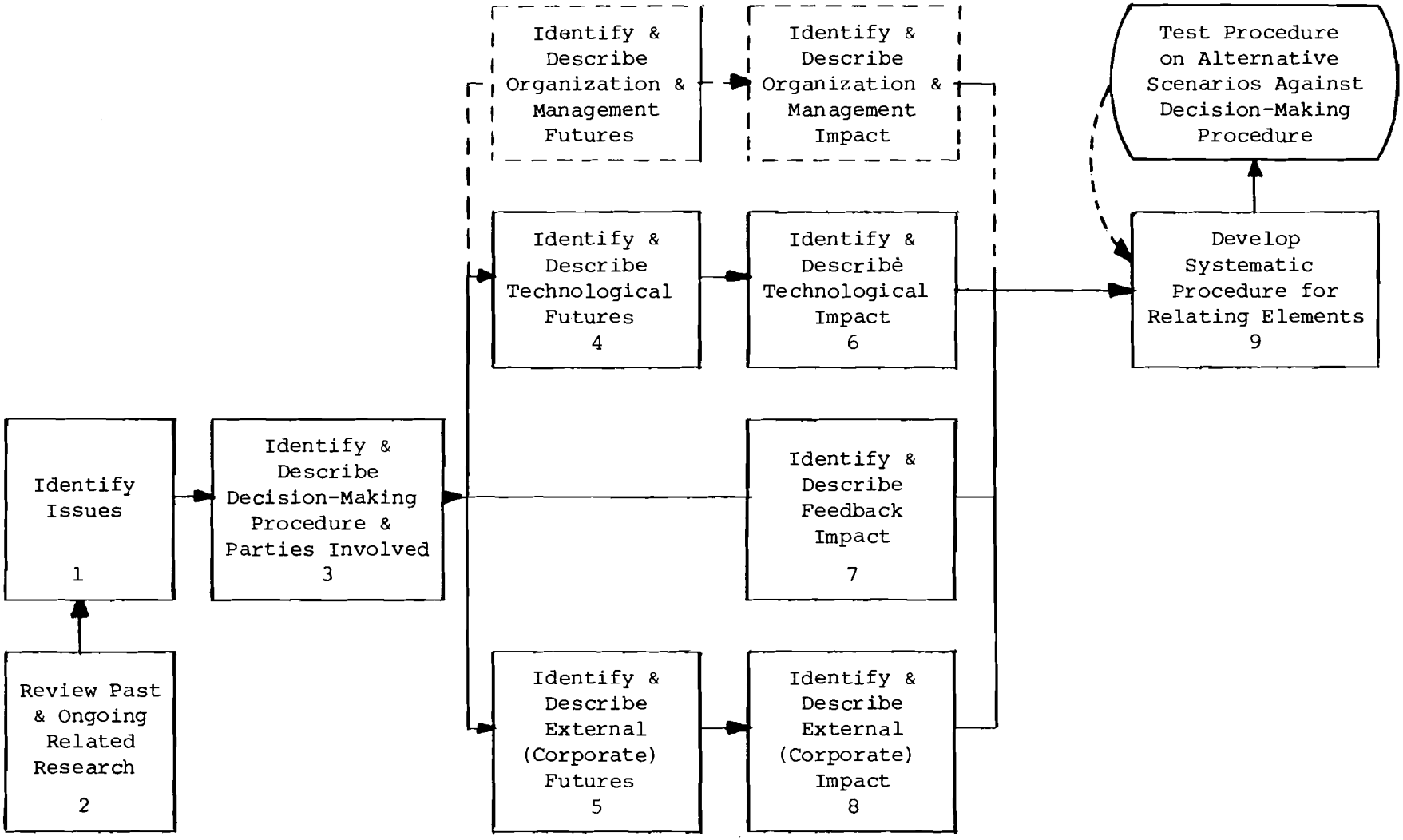

Figure 1. Thesis: The purpose and methods of proposed research.

-- legal restrictions (e.g., rigorous environmental protection rules) will continue to influence mining development.

Future management systems in the mining industry will have to be designed with these conditions in mind. Therefore, a set of general principles needs to be developed that can serve as a basis for management design. These principles should be scientifically proven, yet practical.

Specifically, the formulation of these principles requires answers to several more detailed, practical problems:

-- How to design the management systems for future planned mining basins;

-- How to modernize existing management systems;

-- How to create a climate conducive to effective computer use within the mining industry;

-- How to improve the decision-making process in the mining industry, based on practical findings in operations research, psychology, etc.

It should be stressed that cooperative investigations and exchanging of experiences are needed for solving the above questions and a basis for this should be a comparative and prognostic study.

Coal Mining is Particularly Appropriate for Both Prognostic and Retrospective Research. The coal mining industry has developed worldwide over a long period of time, under a variety of conditions. Even mining technology is not uniform--there can be such a great geological variability between basins, or even within one basin or mine, that different mining techniques and technologies are required. In addition, the nature of coal mining varies by country, and even by coal region, so that coal mining units function under quite different conditions. For example:

-- There is a varied flow of manpower into the mining industry.

-- The social or cultural context under which mines operate also varies.

-- There are different links between the coal industry and other sectors of the national economy. This raises the possibility of incompatible equipment and materials (and, therefore, repairs), between systems.

There are two other characteristics of the coal industry that make it important for study:

(1) Mining operations must proceed in variable and unknown rock masses.

(2) The mining industry plays a central role in the overall national economy. That is:

-- It is important for other processing industries;

-- Settlements can develop that are totally dependent on coal mining.

Because of the complexity of this industry and the great variety of conditions under which it functions (and all the factors listed above), the use of systems analysis is particularly appropriate for this research.

Research Goals

In the course of research on this proposal, we intend to complete the following steps:

(1) A comparative analysis of different management levels in coal mining units and other economic units working for the mining industry. This analysis will employ a uniform research method, discussed below.

(2) Predictions of optimal operating standards for coal mines based on a categorization of the mines into homogeneous groups.

(3) By synthesizing the results of steps (1) and (2), we can contribute to systems studies relevant to the following disciples:

-- organization and economics of the mining industry,
-- management organization;
-- designing integrated mining plants.

Point number (3) should be explained in more detail. Given the basic differences between capitalistic and socialistic economies, and the varied philosophies and methodologies that make up organization and management theory, we cannot expect to develop one definite and compact theory of organization. However, our research can contribute to the development of general rules of organizational development; i.e., the conditions that determine organizational development, functioning, size, etc. Very good examples of previous research on this topic include work by T. Kotarbinski (1969) and J.G. Miller (1969).

Other work, by both Professor D. Gwisziani and the members of our research team, can provide the theoretical basis necessary for developing such general principles. This approach differs from the "situational" organization theories. There are many features of mines, unions, and related enterprises that are common across countries. It is for this reason that we hope in the future to develop a large set of integrated principles and models for designing and improving management systems. This work will also provide the opportunity to compare findings and exchange experiences.

Research Method

The research will proceed by reviewing the research currently being done on modelling the development and functioning of industrial organizations.

More specifically, this involves:

(a) A comparison of the current theories describing the development of management systems at the enterprise and union level.

(b) A similar comparison and evaluation of management systems in the coal industry.

Research conducted at IIASA provides a useful framework for comparisons of this sort. In a recent IIASA Collaborative Paper, Dobrov, McManus and Straszak (1979) develop the "S-IOT" principle (Systems-Integrated Organized Technology). This concept provides a clear methodological base for analyzing the dependencies between organization and management science, and, on a more practical level, the links between technical and economic systems. The authors identify three components of technological systems:

(1) Software--programs, algorithms, etc.

(2) Hardware--computers; technical equipment.

(3) Orgware--a set of organizational arrangements that uses human, institutional and technical factors to support the interaction of technology and external systems. On the macro level, orgware encompasses economic and legal regulations (e.g., prices; tax systems); on the operative level, it includes management procedures, manpower training, and the organizational climate.

The authors stress the importance of integrating all three components in technical systems; orgware should be an integral part of the system, not external to it. Specifically, the authors envision management systems that would ensure the following:

-- Positive attitude of the management staff toward innovation;

-- Full use of the knowledge and skills available in the system.

The authors also favor great flexibility in the organizational structure of management systems.

In our opinion, the S-IOT concept requires theoretical improvement. It should be more detailed; that is, the basic components of a technological system need to be further differentiated into more particular elements. Also, "orgware" should be more precisely defined in terms of the principles that have already been developed in management organization theory.

The general philosophy of this approach arises from the effective activity of praxiological directives (Kotarbinski 1969).

Data Collection

Data needs to be collected that will be used to develop numerous descriptive parameters. These parameters describe various aspects of the economic units within the mining industry (mines, unions), such as the technological and organizational level of the unit, the mining technique involved, and the internal and external conditions under which the unit operates. These data can be later amended through interviews, questionnaires, discussions, etc.

The exact nature of these data can be adapted to fit the needs and the existing statistics of different countries. These measurements are usually aggregated. Further characterization of the mines will require supplementary studies dealing with:

-- External disturbances, and how the system reacts to them.
-- The organizational milieu in the mine. This specifically concerns how decision-makers react to different situations.
-- Internal disturbances.
-- Information dissemination.
-- The decision-making process, especially regarding the level at which decisions are made.
-- Organizational structure.
-- Disfunction.

We have recently completed pilot studies in Poland that dealt with several of these topics. The studies were designed to generate sufficient data for further research, and were conducted in two unions with several mines, and in other economic units related to the mining industry. Data were gathered from standardized interviews and questionnaires sent to decision-makers in all levels of management. The questions concerned:

-- The production process, the decision-making process, and the information dissemination process at both the mine and union levels.
-- The linkages connecting these processes.
-- The types of information used in the decision-making process.
-- The function of the computer system and an evaluation of the information stored there.

This year we will expand this research by studying the organizational climate in the mining system, and by investigating system disturbances from both internal and external sources and methods to eliminate these disturbances. Thirty mines will be included in this study.

Data Analysis

There are two steps to the analysis:

(1) Sorting active mines into homogeneous groups.

(2) Formulating "development measures" for the individual mines within each group.

We will use two mathematical methods to categorize the mines: the Wroclaw taxonomy method and the random variable multidimensional grouping method.

We have already conducted a pilot study (Kozyra 1976) using data collected from every mine in our mining industry. The mines have been described by means of the following parameters:

x_1 : capital investment as a whole (in thousands zlotys),
x_2 : the annual output (in tons),
x_3 : productivity of labour (kg; working day),
x_4 : average temperature in the faces (in $^{\circ}C$),
x_5 : average seam inclination (in degrees),
x_6 : average face thickness (in meters),
x_7 : average length of the working face (in meters),
x_8 : water inflow to the mine (m^3; min),
x_9 : average mining depth (in meters),
x_{10} : average daily short wall advance (meter; working day),
x_{11} : average daily face advance with the hydraulic filling (meter; day),
x_{12} : average daily advance of the longwall with caving (meter; day),
x_{13} : proportional output from mechanized longwall faces (in percent),
x_{14} : shifts (the number of shifts per day),
x_{15} : time of working in the face (minutes),
x_{16} : labour costs (zloty; tons),
x_{17} : material costs (zloty; tons),
x_{18} : amortization charges (zloty; tons),
x_{19} : costs of energy (zloty; tons),
x_{20} : preparatory work intensity (meter; 1000 tons),
x_{21} : average daily advance of the rock gangways (meter; day),
x_{22} : average daily advance of rock--coal gangways (meters; day),
x_{23} : average daily advance of the coal gangways (meters; day),
x_{24} : employment in the industrial group--workers (the number of persons),
x_{25} : employment in the industrial group--engineers, technicians (the number of persons),
x_{26} : employment in the industrial group--administration staff (the number of persons),
x_{27} : employment in non-industrial group (the number of persons),
x_{28} : absenteeism of workers in the industrial group (in percent),
x_{29} : degree of works by the job (in percent);
x_{30} : average wage (zloty; year),
x_{31} : value of gross fixed assets (thousand zlotys).

This sorting was performed on the basis of two factors: the "technique-organization" and the "mining-geological" features of each mine. Such a sorting helps determine the mutual similarity of mines, keeping in mind the restrictions resulting from the statistical assumptions made.

One other algorithm, the "random variable multidimensional" method, was used in this pilot study. This provides a means for grouping the mines into related subgroups, and even for joining these subgroups into homogeneous categories. It also enables the measurement of relative distance on a given scale.

The second step in the analysis involves the formulation of a "development measure" for individual mines within the homogeneous group. This degree of mine development can be determined in the following manner. For each mine cluster:

-- A hypothetical abstract mine is drawn up using the extreme values for specific diagnostic features.

-- The deviation of an individual mine from this hypothetical mine can then be calculated.

-- Individual mines are sorted into groups based on decreasing value of the development index.

Determining the Development Trends of Each Homogeneous Group

There are four steps in this part of the study:

(1) We will formulate a "development prediction" measure for each homogeneous group, applicable to each mine within that group.

The features of this predictor would be determined using various econometric and heuristic methods. It will be made up of an adequate number of varied components to reflect the importance of system integration in mining development (i.e., the S-IOT concept).

(2) Using the G. Nadler concept and morphological methods, we will develop "indirect" development measurements between the analyzed mine and its predicted degree of development.

(3) Develop a method of data collection that will accurately reflect these indirect measures, and can act as a link between the present state and the predicted development for each mine.

(4) Tabulation and analysis of the collected data.

In our opinion the proposed study has other advantages--taking into account IIASA's possibilities and circumstances. Namely, they can apply the WELMM data bank and develop it to organizational aspects of the collieries, next they could give possibilities for applying the Energy Project results for our needs.

Synthesis of the Results; Conclusions

In the course of our research, we expect to complete indispensable studies relating to sections 1.1 and 1.2 of our proposed outline (Attachment 1):

Subsection 1.1.1:

"Studying the use of modern organizational structure under coal mining conditions." We are currently working on several projects that compare those organizational structures that function properly with those that do not. In addition, we are studying various organizational approaches that can be widely used in the mining industry (e.g., different types of work team structures).

Subsections 1.1.2, 1.1.3, 1.1.4 are:

-- Research on implementing new uses for computerized data base management and retrieval systems.

-- Assess the advantages of using large data bases for planning purposes in the mining industry.

-- Determining what changes in planning and organizational processes would result from computerization.

Computerized management systems for production, investment, and auxiliary and service activities have already been developed and implemented in the Ministry of Mining. They play an important role in improving management methods in the mining industry. Computerization permits great improvements in record keeping, evaluating current operating effectiveness, and optimizing economic strategies. The principle of computerization has been accepted at all decision-making levels (according to accepted priorities) and has been introduced into all types of mining activities.

Based on past research, the Management Computerization Model has been developed. This model illustrates specific ways that management may use computer systems.

The model is comprised of three groups of "analytical-accounting" systems, and three groups of "planning" systems. Each group plays a clearly defined role in the management process.

The "analytical-accounting" systems aid in record keeping and also evaluate the effectiveness of current operations. The three groups are:

(1) Systems related to the comprehensive evaluation of mining technique and technology encompass all the mines and investment "partners" in the mining industry. These systems handle the analysis and evaluation of economic effectiveness of the production and investment processes, given the method, technology and the operating conditions involved. A comparative analysis is also involved.

(2) Basic analytical-accounting systems help modernize the entire record keeping, recording, and accounting processes. This aids in evaluating the effectiveness of individual mines and mine-related enterprises (e.g., repair plants, transportation, forwarding enterprises, etc.). It also decreases time-consuming administrative work and shortens the time involved in accounting and analysis. In addition, these systems can help determine the direction that planned mining activities will take.

Dealing with such basic financial aspects of mining as materials management and wages, these systems handle the most mundane and yet the most important accounting activities in mining and related industries.

(3) A group of special systems deals with the evaluation of both the centralized service units that support the mining industry (e.g., the Coal Sales Board) and also for scientific R&D support. These "special systems" computerize all functions that are unique to the support units; their main purpose is to evaluate the effectiveness of a given support unit for the entire mining industry.

The Management Computerization Model also contains three groups of planning systems. They are designed to forecast the effectiveness of planned activities and to select optimal planning strategies:

(1) Production and investment planning systems obtain data primarily from Comprehensive Evaluation Systems (Group number (1) above). Using mathematical methods, they seek to optimize the effectiveness of one and five-year production plans, and also plan out investment strategies for the entire mining industry. These systems deal with problems that have the greatest influence on overall management effectiveness for the mining industry as a whole.

(2) Planning systems for auxiliary activities perform tasks similar to the first group, but on a smaller scale. These systems help develop long-term investment strategies and production plans for the coal mines as well as short-term operative planning for unions and mining-related enterprises (e.g., construction).

(3) Planning systems for service activities computerize the planning process for those activities that are controlled, as a rule, by the centralized units of the mining industry (coal sales, mine timber supply). The main purpose of these systems is to close the decision-making cycle within the service industries.

The three "analytical-accounting" groups employ a total of twenty subsystems; the three "planning" groups use fifteen subsystems.

At the present time (end of 1978), all coal mines are serviced by the integrated analytical-accounting systems. The basic planning systems have been prepared for general use.

In light of the current state to computerization in the Polish mining industry, research on implementing control systems in mine management and on the possibility of constructing a large, integrated, data base, is very important and particularly relevant for planning purposes. Also important is the development of a computer system employing minicomputers and microprocessors.

By furthering current research and following up on the present trends toward computerization, the Polish mining industry can possess a fully computerized management system. As a result, the industry will become a more compact and resilient economic body, characterized by maximum efficiency and management effectiveness.

We expect to do research concerning the development of computer systems within this IIASA study. As already mentioned, it would be advisable to conduct this research according to a uniform method. We suggest that an appropriate method would be the research cycle presented in this paper.

We also intend to study the relationship between the size of the economic unit (e.g., a mine, or union) and its production effectiveness. This can be done by expanding the data analysis to include a parameter describing system size. The exact definition of such a category must be accurate from the viewpoint of systems analysis.

We recognize that the question of optimal mine size is pertinent to decision-makers. We will try to present the initial results of our work on this topic at the IIASA conference in June. We expect that the results obtained from the successive stages of work will yield useful and practical policy recommendations and will also contribute significantly to organization and management theory.

Topic 2--Factors Stimulating Deposit Exploitation

Organizational and technological factors stimulating deposit exploitation. Specifically, this involves:

Section 2.1 the use of systems methods to develop economic indices that measure the profitability of exploiting raw materials.

It is essential to develop proper indices to determine the effectiveness of raw materials exploitation. These indices can then be used to develop guidelines for the national, objective use of raw materials on a global scale.

The common nature of this problem is reflected in the features of raw materials management at the present:

-- The irrational output and irrational use of raw materials that are in noticeably short supply.

-- Lack of a common administrative system, and lack of economic and engineering incentives for creating a rationale for excavation, processing and use of raw materials on a global scale.

Forecasts of raw materials shortages, particularly of fossil fuels, reflect the economic profitability of deposit exploitation.

The results of several studies, such as those conducted by the Polish Academy of Science Energetic Committee and IIASA, and findings presented at the Energetics World Conference in Istamboul (September 1971), all forecast the following:

-- a general shortage of fuels is expected in the 1990's;
-- several crises will occur in the development of the economy.

This justifies the need to undertake research in the following areas:

(1) Verifying the accuracy of existing methods for measuring exploitation effectiveness and "first driving" deposit descriptors.

(2) Formulating objective, general, and comparative indices of this effectiveness.

(3) Develop and justify an importance hierarchy for these indices.

Additional motivations for research include:

-- Need to use a systems analysis approach to calculate the effectiveness of raw materials exploitation.

-- Existing methods of estimating the effectiveness of deposit exploitation do not take into account so-called "ecological costs".

-- The present criteria used to determine deposit exploitation profitability, while they vary by country, are generally too liberal for rational deposit economics.

Research Goals

The goals of this research area:

(1) Listing the various methods cited in different publications that are used to determine:

-- Economic evaluation of mineral raw materials resources;

-- The value of the useful minerals in a deposit;

-- Geological and economic criteria used to balance resource;

-- Evaluation of ways to measure deposit loss in all aspects of mining: design, first drive, and exploitation of the deposit.

(2) Comparing these methods according to a uniform method.

(3) Developing general guidelines for measuring deposit profitability. That is, we intend to develop general principles that should act as incentives for the rational exploitation and utilization of deposits; these principles should be applicable to all countries, regardless of the economic system involved.

In order to achieve these goals, it is necessary to develop a uniform comparative methods based on systems analysis.

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ATTACHMENT 1

MAIN TOPICS OF INTEREST TO POLISH INSTITUTES

1. The theoretical and methodological aspects of programming the mining industry development with particular stress on the progress and adaptation of the systems approach to which statements have been developed at IIASA.

1.1 Methodological aspects of modernization and designing the the management systems in the mining industry.

1.1.1 Recognition of the possibility of using, in coal mining conditions, modern organi ational structure solutions.

1.1.2 Research in the scope of new solutions in creating computer systems based on data bases.

1.1.3 Evaluation of advantages gained by using large data bases in the mining industry for planning purposes.

1.1.4 Defining the tendencies of change in organizational processes and planning of computer technical development.

1.2 Interdependence study concerning the size of the economic unit and its production effectiveness.

2. Organization and technological factors stimulating the deposit exploitation profitability.