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Background Paper for Seminar on Organizational and Management Problems Arising from Technological Changes - Coal: Issues for the Eighties

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BACKGROUND PAPER FOR SEMINAR ON ORGANIZATIONAL AND MANAGEMENT PROBLEMS ARISING FROM TECHNOLOGICAL CHANGES--COAL: ISSUES FOR THE EIGHTIES

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PREFACE

The Core Task of the Management and Technology Area included a subtask devoted to industry studies entitled "Issues for the Eighties"; the first to be studied was coal. Although this study is to terminate at the end of 1981 it is hoped that IIASA will continue to lend its name and support for holding a seminar each year on the problems of world coal prospects.

At previous IIASA seminars on coal mining problems it was unanimously requested that such meetings should be continued. In this respect the Institute for Organizational and Management Problems of the Polish Academy of Sciences and the Computer Center for the Polish Mining Industry agreed to sponsor the next seminar which will be held in Kokotek (near Katowice) Poland, in October 1981.

This seminar will be devoted to current developments in the systems assessment of the technological changes in coal mining and data-processing at a colliery. Special attention would be paid to the influences of advanced new mining and information technology on the organizational, managerial, and social subsystems. This paper outlines some issues which, it is hoped, will provoke discussion.

Any comments by the participants or those who are interested in the subjects of the seminar would be of great interest to the organizers in helping them prepare a comprehensive program which will be of interest to those attending.

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ORGANIZATIONAL AND MANAGEMENT PROBLEMS
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COAL: ISSUES FOR THE EIGHTIES

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> "If we are to continue to advance the frontiers of technology in mining, then the application of any new knowledge has to be translated into practical mining which depends on men, machinery and money being so organized, arranged and used as to provide a firm basis on which we can take the next step forward into the future." (Crockett, 1980)

PROBLEMS OF ADVANCED MINING TECHNOLOGY

According to the World Energy Conference (Istanbul, 1977), world demand for coal in the year 2000 will be in the region of 5.8 billion tce which is more than twice the 2.7 billion tce of coal produced in 1977, and the demand will have increased more than three times that in 1977. In order to meet the growing demands for coal, it is necessary to accelerate the innovative processes in coal mining and coal utilization, as well as investing in new mine capacity for coal production.

Only advanced new coal mining technology is an indispensable factor in reducing the technical, economic, social, and environmental disadvantages involved in coal mining processes. It is now clear that new coal mining technology will be created by:

- o dramatically changing the machinery and equipment used in conventional mining methods, and
- o future unconventional mining methods.

Principally the practised methods of underground coal extraction in the world could be divided into two groups: room-and-pillar and long-wall mining; even though the long-wall mining method is by far the most widely applied system, especially in Europe. In Poland, for example, the average output of one mine increased from 5850 tons per day in 1970, to 9612 tons per day in 1979; the average output from one mining level from 2346 to 3743 tons per day; and from one loading point from 643 to 1144 tons per day in the same period. Mechanization of long-wall faces and particularly the use of mechanized supports, apart from systematic mines, (e.g., building new levels, shafts, coal preparation plants, etc.), have greatly influenced such a considerable increase in output. The length of face front equipped with mechanized support was 2,926m at the end of 1970 and 56,808m at the end of 1979. As a result the output share increased from 3.0% to 61,1% (Lakomy 1980).

From 1970 to 1979 the proportion of fully mechanized faces equipped with shearer loaders in coal mines of the Federal Republic of Germany increased from about 22% to 36% and the proportion of output produced on those faces during the same period jumped from 20% to approximately 42% (Schüpphaus 1981).

The trend of costs, output and manning per face in the UK is shown in Figure 1 (Crockett1980).

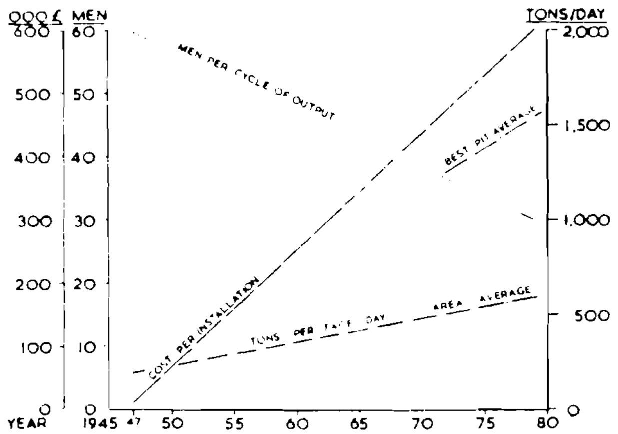

Figure 1

However, the long-wall system is growing fast throughout the US as well. In 1969 there were only 15 installations in US coal mines; this number has now grown to more than 80 in 1979. During those 10 years the percentage of deep mined coal extracted using the long-wall system increased from less than 1% to 4.5% (Chironis 1979).

As far as the long-wall face is concerned the basic system has remained the same since the turn of the century due to the fact that machinery and equipment has changed so dramatically since that time that the cost of equipping a face today compared, for example, to 40 years ago, involves a very large cost difference. Crockett (1980) gives excellent evidence of this, see Tables 1 and 2.

In Poland during the last decade a large proportion of the outlay for equipping a long-wall face increased rapidly to reach a value exceeding as much as 300 million zł at faces equipped with imported shield supports. A characteristic phenomenon in the structure of outlays is the decrease in value of the extracting and loading machine. The structure of outlays borne for the equipment of a long-wall 180m long, depending on type of supports, is as follows (Fabian, et al 1980):

with Valent supports	- 7,873,000 zł including the value of a 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 technologies actually used within the long-wall mining method do not take full advantage of potential possibilities of existing machines and installations, nor of the available working front. The investigations carried out into prognostic tendencies of technical progress in hard coal mining and the recognition of the need for appropriate innovations extended by keen studies indicate the advisability of developing research work in order to work out new efficient and reliable methods of mining coal seams.

In the next 10-20 years particular attention should be paid to practical and organizational mastering of the long-wall mining

Table 1 Face Equipping: Estimated Cost in 1947

	£
2 x A.B. 15" coal cutters	2,040.00
2 x 15" scraper chain conveyors	2,100.00
2 x electric coal boring machines	195.00
2 x electric stone boring machines	195.00
signalling	20.00
controlling switchgear	875.00
trailing cables	835.00
	6,260.00
1 x 20" scraper chain conveyor (100 yards long) conveyor switchgear and cables	1,740.00
Total	8,000.00

Table 2 Face Equipping: Estimated Cost in 1979

	£
2 x AS. 16/175 ranging drum shearers . . .	73,000.00
A.F.C. C/W-1 x 120 H.P. & 1 x 65 H.P. motor . .	53,000.00
boring machines	2,000.00
signalling	9,000.00
controlling switchgear	27,000.00
trailing cables	13,000.00
	177,000.00
self advancing stage loader conveyor switchgear and cables	23,000.00
	200,000.00
powered supports, hydraulic equipment, also stable/roadhead hydraulic props. & bars . .	400,000.00
Total	600,000.00

technology by a continuous method which includes the multiple cutter-loader mining teams in the initial development stages.

As long as the shearer loaders were chain hauled, all attempts to operate several shears simultaneously on one face failed. Such limitations no longer exist, for example, Eicotrack. It is now possible to equip a shearer loader with two haulage units. This might be necessary to confer the required haulage pull on large and heavy machines or to operate them in steeply inclined seams. As was introduced, (Fabian et al 1980) the multiple-shearer-loader mining system for which a prerequisite is the chainless haulage system, would challenge new areas of applications for shearer loaders.

In summarizing the above considerations it ought to be stressed that those mining technologies actually used do not take full advantage of potential possibilities of existing machines and equipment, nor of the available working front. Particular attention in the prognostic tendencies of technological progress in mining in the next 10-20 years, should be paid to mastering the practical and organizational technology of long-wall mining by a continuous method, which includes in the initial stages of development multiple cutter-loader mining systems. Therefore, the following thesis can be formulated: there is a practical possibility for increasing output per unit of a coal face and its efficiency and safety of work through appropriate combinations of the currently known and actually designed equipment.

There are many eminent specialists speaking about facing up to the technological challenges of the 80's which will involve appreciating the benefits and problems posed by micro-processors. For example, in Czechoslovakia a lot of effort has been paid to an entirely new mining method, which has been called "Underground Exploration of Coal Seams by the Method of Concave Centrifugation Continuous Caving Mining" with the robot device "Efides" and hydraulic transport and exhaustion of mixed air and CH_4, CO_2, CO, H_2, etc. (Petras 1980).

The application of micro-processors in the auxiliary and transportation processes will create a number of technological changes and undoubtedly bring new problems. Taking into account the presented remarks on new mining technology as appropriate combinations, and of current and actually designed equipment the following questions can be formulated:

- How long can the long-wall system of mining continue to absorb the ever increasing costs of equipping a mechanized face as new equipment is developed?
- Is there a barrier to this rising trend?
- What are the future tasks for mining engineers, colliery craftsmen, and managers as new technology and machinery is developed for application in the long-wall mechanized system?
- How can the deposit losses due to high mechanized mining technology be reduced?

The next portion of new mining technology are unconventional methods. These methods can be indicated by:

-- cutting by pressurized water,
-- underground gasification,
-- chemical combination,
-- solvent digestion,
-- microbiological degradation.

One of the most promising methods appeared to be underground gasification. This technique could also be applied to extracting fuels from deposits which proved unsuitable for mining with conventional methods.

Different specialists share the same opinions concerning potential prospects of different unconventional mining methods, and different emphases are given on the above mentioned methods in different countries which are mostly interested in developing their own coal mining industry.

One can be sure that some of these methods will be utilized. In order to overcome new problems and barriers involved, it would be necessary to undertake detailed systems studies. The utilization of unconventional methods in coal mining will change the general systems characteristics of future collieries, i.e., their type and size, and will also influence their social and organizational subsystems.

The following general questions arise from the above:

- o What kind of rules are created by these development processes in the coal mining industry?
- o How do the technological changes involve the organizational changes and how will the social system be influenced?
- o What kind of organizational, managerial, social, economic, and environmental barriers can one expect to find in the further progress of coal mining?
- o How can systems analysis assist in solving the above mentioned problems?

Among numerous problems arising from technological changes that are created up until the present, and the future progress of coal mining and utilization, the following have been chosen to be topics of our October meeting:

- o Barriers to advanced mining concepts.
- o The impact of technological changes on environmental and demographic characteristics of a colliery.

PROBLEMS OF ADVANCED DATA-PROCESSING TECHNOLOGY

The rate of change and development in this field is so high that it is only possible to outline some of the most probable general trends.

1. It is now rather clear that qualitative changes occur in basic hardware technology. Small computers (small microprocessor-based computers) enter new fields of applications where, hitherto, they were not economically or technically feasible. The manifold forecasts in hardware technology have shown that micro-computers will soon have a capability similar to today's powerful computers and that large-scale computing can be done on hardware at much lower cost than ever before (Fick 1980).
2. Up until the present existing management information systems (MIS) have had little impact on the decision making process at the middle and senior management levels and

appeared to be inefficient for their users (Fabian et al 1980). In this respect efforts will be made to create rather small, interactive systems (so-called Decision Support Systems--DSS, Fick et al 1980) with a fast response enabling managers to have access to a variety of data and small models to support them in understanding their task and to improve the decision process.

The following questions arise:-

- o How will this advanced data technology affect the dimensions of a colliery's organizational stucture?
- o How do management sciences and practice solve the new problems created by DSS?

Some aspects of these questions will be discussed, bearing in mind the necessity of improving the management system of a colliery.

ORGANIZATIONAL AND MANAGEMENT PROBLEMS ARISING FROM TECHNOLOGICAL CHANGES

Technological innovation theory and the use of technological changes in different branches of the coal industry have provided us with numerous principal rules and references of how to deal with the innovation processes in order to be more successful. This paper considers three of them.

1. The problems and the experiences which accumulate with innovation processes, not only in the coal mining industry, make it obvious that technological changes do not automatically and necessarily mean technological progress or real economic growth, and even less, an actual increase in social welfare and human satisfaction, or organizational progress. Society in general, and organizations in particular, merely react on technological changes through feedback loops, but in a rather haphazard and incongruous manner. It is a challenge to deal with the changes in the organization. Also borne in mind are the technological changes shown by using an integrated model, which should comprise of the following:

- o The examination of different sorts of changes in the organization such as:
  - -- technological changes (new techniques, technologies, products and equipment, etc.)
  - -- changes in the social subsystem of the organization (norms, values, conflicts)
  - -- structural changes (modifications to the power system)
  - -- organizational changes (information network and object distribution).
- o The examination of the mutual influences of these changes which should be conducted in a systematic way. The problem under consideration must be studied as a system--as a dynamic whole--in which components are defined both per se and through their interrelationships.
- o The study of the influences of change in the given organization to its demographic dimensions (size, type, etc.).
- o The examination of the changes in an organization with regard to the mutual influences on its environment.

During the last 10-15 years, within the framework of science and technology (ST) policy and within the various branches of systems analysis, new types of research have been developed using the same elements of such an integrated model. These elements are called technology forecasting (TF), technology assessment (TA), alternative technologies (AT), and the evaluation of R&D (ERT). This set of elements are proposed in an approach called Systems Analysis of New Technology (SANT) which was elaborated at IIASA (Dobrov et al 1978).

The object of this approach is so-called organized technology. The background of this concept arised from a statement that to achieve technological advance, as a rule it is not enough to have a set of technical means or even skilled staff. These must be supplemented by special organizational (in more general terms, socio-economic) innovations. It was then stressed that to achieve success, each modern technological system urgently needs a specially designed organization to provide for the utilization of decision makers' skills and the interaction of this system with other systems of different natures.

It is clear that the above mentioned concepts are not technical devices but rather a change in attitude towards technology and a new approach to better informed decision making in this field. More researchers and skilled practitioners will, however, be needed before practical and useful techniques, based on the systems approach to problems of change in the organization, can be elaborated. The lack of such techniques is, unfortunately, often the cause of failing to improve technology, organization, and decision making processes at the design level--including collieries.

In pointing out these considerations at the colliery level and the subjects of the seminar, it is indisputable that the examinations, forecasting, designing, and control of the technological changes in coal mining ought to be dealt with by using the systems approach. The importance of this statement and of how often it is forgotten and wrongly understood in practice can be proved by analyzing the numerous different kinds of changes that collieries have undergone. It is now rather clear that mechanized mining methods created a change in the working environment for those persons employed at the face. The attitudes of those people have also changed with the passing of time since mechanization was first introduced to long-wall mining. However, this was not immediately considered. Evidence of this has been expressed by Trist and Banforth in their study of different consequences caused by implementing mechanization in British coal mining. Their study included social, psychological, and management consequences of installating long-wall methods which showed that this new production technique was not at all effective and productivity suffered. Thus, economic factors had technical, social, and psychological consequences. The technique of production was subsequently modified to permit greater interaction on the job--morale improved and productivity rose.

The complexity of changes in the social system as a consequence of technological changes was enlightened by an experiment in autonomous working in an underground coal mine in the East of the United States--this is a well-known study called the Rushton experiment (Trist, et al 1978; Goodman 1979).

Another example, which clearly shows the failure of a one-sided approach for making changes in a colliery was the trial of applying the so-called 4-shift working system in Polish coal mines (Lakomy 1980). This system ensured that workers received two free days after working six days. Hence, it was found that those mines equipped with much more expensive fittings could work in a continuous mode (24 hours). The disadvantage of this system, however, proved to be that the free days, normally Saturday and Sunday, happened to fall in an interval of about six weeks for particular workers. This system was not acceptable to the staff and was withdrawn from the coal mines; although the number of working days--about 305-243 days in a year--was obligatory for those working in the 4-shift system. Another undesirable fact was the exploitation of machines and devices which gradually became inefficient. This was caused by the fact that not enough time was given to everyday maintenance and repair work in addition to the lack of free days without output. Therefore, it was impossible to keep the machines and devices on a desirable technical level. This fact was the reason for forming a considerably big reserve, and equipping the mines with expensive mechanized supports causing reduction of fixed assets productivity. Those mines which had been forced to accomplish a large increase in production exerted strong pressure to manufacturers for the delivery of new underground machines and devices.

Finally, the importance of the seminar's subjects should once more be underlined. In the author's opinion it is sufficient to present Chironis's opinion on the use of funds for developing advanced mining equipment in the US. He states:

> It is no secret that although improved safety is a main objective of this funding an equally important goal is to reverse the shocking drop in productivity in coal mines and thus reduce the total cost of mining. Productivity of miners in underground mines has dropped by half in the last eight years, falling from 15.6 tons per man shift in 1969 to less than 8 tons per man shift in 1978.

> Mine operators, however, are becoming more aware of the need for equipment that improves safety as well as productivity. They are not only asking design questions, such as "How well will it work?", "Will it fit into my mining plan?", and "Does it meet federal and state regulations?", but also "Will it reduce chances for accidents?", and "Will it help defend against liability and negligence claims in court?". (Chironis 1979).

2. A new technology is more a matter of countless modifications to some earlier, less specialized, design than to conceptualizing alone. Even the most carefully conceived devices seldom prove to be practicable immediately. It is generally accepted that this new technology must be "put through the mill" and tried out several times before being made operational. It can be stressed that the successful resolution of technological changes depends on existing practical experience. These considerations suggest, therefore, the very important role that experience plays in technological innovation, initially for the mining industry.

   As was previously stressed, while the long-wall face and room-and-pillar systems of today are vastly different to a face say, 40 years ago, the basic system is still the same. But dramatic changes in face equipment have brought about big changes in the level of manpower on colliery books, and in the needed skills of face crew and officials. The change in attitude of these miners and face officials, the changes in the organizational structure and in the management system of a colliery are the consequences of gradual technological changes which have greatly depended on past experience. These considerations could then be termed as a "learning by doing" approach for innovation processes in the mining industry; experience is gained as a consequence of technological and organizational changes.

3. Technological changes and the changes in the organizational and social systems of a colliery have influenced environmental and demographic dimensions (initially, size and type). The size and type of a colliery in the 50's was different than a colliery in the 70's and will be different in the 90's. The following questions arise:

- o How are the technological and organizational changes memorized by the colliery-system as a whole?
- o How will new mining technology (for example, mixed conventional and unconventional methods) create the type and size of a colliery in the future?
- o How will these changes influence the organizational structure and management system?

Answers to these questions are very important because any rectification is very costly in a colliery.

The problems mentioned in this paper touch on the great number of different topics for detailed discussion and examination. From this comprehensive bulk of problems some have been chosen as the subjects of the seminar (see Appendix A).

We hope discussion during the seminar will be a good opportunity for the exchange of the ideas and experiences within these topics. Apart from this, it is thought that it would be of interest to the participants to discuss the methodological aspects of research and design activity in order to identify the way, and approach, in which systems analysis can assist in solving these problems which, as it is hoped has been introduced, are major ones for coal mining development.

The implementation of a systems approach in examining the mutual influences and consequences arising from technological changes in mining and data processing activity at collieries (which is proposed to be the main subject of the seminar) is by no means a purpose in itself. It can also serve as the basic means of designing and managing the technological and organizational changes. The elaboration of practical and useful techniques for managing these changes bring about some questions which should be answered:

- o How can existing management systems be modernized on different organizational levels of the coal mining industry so that they would be more innovative?
- o How can the organizational structure and management systems of a colliery successfully meet the consequences arising from innovation processes?

- o How can the design of information systems be dealt with in order to have more impact on the decision making process at middle and senior management levels in a colliery?

We hope, through discussion, to perhaps change the opinions and proposals on these questions making a background for cooperation between different institutes to help solve these problems.

POSSIBLE ROLE IIASA COULD PLAY

IIASA undertook to conduct a pilot study to identify the main issues confronting the coal industry up to 1990. Due to a number of different reasons it has been decided to terminate investigations into "Coal: Issues for the Eighties" although it is hoped that IIASA will continue to lend its name to, and hopefully support, future meetings and seminars.

The results of our efforts in IIASA's coal study, the good experiences gathered during seminars, and the interest expressed by representatives from NMOs in the subjects which are planned to be the main issues of future seminars, allow us to believe and hope that these meetings on coal mining subjects will continue to be investigated. Those subjects which were discussed in previous seminars and those which are considered to be the main issues of future meetings are directly connected to planned activities in IIASA, in particular to:

-- Industrial Development (GEN)
-- Regional Development (GEN)
-- Innovation Management (MMT)
-- Information Technology (MMT)
-- Risk Management (MMT)
-- Management of Conflicting Social Objectives (MMT)
-- Resource Assessment and Accounting (REN).

It should be stressed that it is a logical process that research on "Coal: Issues for the Eighties" be carried out at IIASA. Previous seminars have resulted in a current state-of-the-art account on the use of Operational Research and Systems Analysis in planning activities in the coal industry. In addition, general problems concerning successive stages of planning, design, and decision making activities were pointed out and the way in which systems analysis could assist in solving these problems were discussed.

The next seminar is devoted to organizational and management problems arising from technological changes. It is hoped that this will be an excellent opportunity for detailed discussion on specific coal mining problems and to confront the general issues of dynamics and the complexity of industrial development in the future. In my opinion, bearing in mind the problems discussed during coal seminars and the subjects outlined in IIASA's Research Plan (1982-86 Draft), future meetings on coal issues (or on the mining industry in general) could contribute to activities planned in MMT, REN, and GEN areas.

Possible subjects for future seminars could be:

- Loss of energy resource deposits and new mining technology
- Regional development problems on such cases as:
  - mining regions, prospects and constraints,
  - study of the regional impact of large scale synthetic fuel production
  - risk and disaster management problems in the mining industry
  - management of conflicting objectives arising from technological changes in the mining industry.

CONCLUSIONS

The coal mining industry is particularly appropriate for a comprehensive and international study because it is a critical energy industry faced with expectations of greatly increased demand before the end of the century, and with the need to make major investment to decisions at a time when existing capacity is not fully utilized. Markets in the future may be very differently located from the present, and the transport situation needs to be reassessed. The future use of the product is uncertain--it might be needed for electricity generation, gasification, liquifaction or other end uses. The production technology is undergoing change, and the impact of the computer is only just beginning. At the same time, concern about pollution of earth, water, and air is growing--leading to major regulatory controls of various kinds. It is an industry in transition, and most of these critical issues are appropriate subjects for systems analysis.

Moreover, the coal mining industry has developed over a period of time under a variety of conditions, and has a good record of international collaboration. This gives a good basis for comparative studies that can be used to provide results of general applicability. Two recent meetings, the 10th World Mining Congress in Istanbul in 1977 and the UNO Coal Seminar in Katowice, Poland in 1979, have confirmed the potential return from developing international scientific cooperation in the scope of coal mining. Systems analysis has, as has been stated, a major part to play in tackling the problems of coal mining development.

The author is convinced that research efforts, the results from different case and field studies undertaken by different institutes which have contributed to this project, the conclusions gained from seminars, and the experiences of those people interested in mining problems, are all adding to IIASA's ability to contribute to an improved understanding of the general questions which will, it is hoped, be solved in IIASA's activities mentioned above. On the other hand, IIASA's results on the general research items (see IIASA's Research Plan 1981-85) will create a fruitful background for solving the more detailed problems of the mining industry.

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APPENDIX A

SUGGESTIONS FOR SESSION TOPICS

1. Barriers to Advanced Mining Technology
2. The Impact of Technological and Organizational Changes on Demographic and Environmental Characteristics of a Colliery (Size and Type)
3. New Mining and New Data Processing Technology as the Issues for the Management of Men and Machinery at a Colliery
4. Organizational Changes Involved by the Use of New Technology
5. References for the Design of Innovative Management Systems for a Colliery.

It is proposed to confine discussions to:

-- Technological changes in coal extraction processes.

-- Changes of information technology on colliery levels.